OF

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WEED

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DECEMBER 6, 7, 8, 1949

SIOUX FALLS, S. DAK.

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DECEMBER 12, 13 AND 14

HEADQUARTERS — SHROEDER HOTEL

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Future Meetings ..... B. C. Swenson
Ways and Means ..... T. L. Aamodt
Terminology ..... W. C. Dutton
Resolutions ..... C. A. Bower

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Manitoba Dept. of Agri., 169 Legislative Bldg., Winnipeg, Canada

R. S. Dunham, President, N.C.W.C. Conference
Division of Agronomy & Plant Genetics, University Farm, St. Paul, Minn.

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A. L. Bakke, Dept. of Botany, Iowa State College, Ames, Iowa
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Lyle Derscheid, Dept. of Agronomy, South Dakota State College, Brookings, S. Dak.
George Knowles, Dominion Experimental Farm, Ottawa, Canada
John Miller, U.S.D.A. University Farm, St. Paul, Minnesota
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V. M. Woestemeyer, Dept. of Agron., Kansas State College, Canton, Kansas
J. W. Zahnley, Dept. of Agron., Kansas State College, Manhattan, Kansas

II. *Annual Weeds*

A. H. Larson, Dept. of Plant Path. & Ag Botany, University Farm, St. Paul Minn.

III. *Field Crops*

(legumes) K. P. Buchholtz, Dept. of Agron., University of Wisconsin, Madison, Wis.
(sorghum) W. C. Elder, Dept. of Agron., Oklahoma A & M College, Stillwater, Okla.
(s. beets) E. A. Helgeson, Dept. of Botany, N. Dak. Coll. of Agri., Fargo, N. Dak.
(corn & sorghum) C. A. Holm, Dept. of Field Crops, University of Missouri, Columbia, Mo.
(grasses) Dayton Klingman, U.S.D.A., Coll. of Agri., Lincoln, Nebr.
(corn) Oliver C. Lee, Dept. of Botany, Purdue University, Lafayette, Indiana
(grasses) G. L. McCall, E. I. DuPont de Nemours & Co., Kansas State Coll., Manhatta
(sp. wht., oats & barley) P. J. Olson, Div. Plant Sci., University of Manitoba, Winnipeg, Can.
(w. wheat) Wm. Phillips, U.S.D.A., Exp. Station, Fort Hays, Kansas
(flax) R. G. Robinson, Div. of Agron., University Farm, St. Paul, Minn.
(grasses) N. E. Shafer, Dept. of Agron., Coll. of Agri., Lincoln, Nebraska

IV. *Pre-emergence*

(corn & sorghum) R. F. Fuelleman, Dept. of Agron., University of Illinois, Urbana, Ill.
(barley & oats) W. C. Shaw, Dept. of Agron., Ohio State University, Columbus, Ohio
(miscl. crops) F. W. Slief, Dept. of Agron., University of Illinois, Urbana, Ill.
(sugar beets) Chas. R. Swanson, U.S.D.A., N. D. College of Agriculture, Fargo, N. Dak.
(soybeans) C. J. Willard, Dept. of Agron., Ohio State University, Columbus, Ohio

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Glenn Viehmeyer, University of Nebraska, Substation, North Platte, Nebr.
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L. W. Melander, U.S.D.A., University Farm, St. Paul, Minn.
D. A. Savage, U.S.D.A., So. Gt. Plains Sta., Woodward, Okla.

VII. *New Herbicides*

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VIII. *Physiology & Chemistry*

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R. F. Fuelleman, Dept. of Agron., University of Illinois, Urbana

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Clyde A. Bower, Chairman
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Geo. M. Briggs, Uni. Wisconsin, Coll. Agri., Madison, Wis.

C. H. Schrader, Lyon Chemicals, Inc., 2305 Hampden, St. Paul, Minn.

Publicity

Glenn Viehmeyer, Uni. Nebr. Substation, North Platte

Proceedings of the Sixth Annual Meeting

OF THE

North Central Weed Control Conference

Sioux Falls, South Dakota — December 6, 7, 8, 1949

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Regulatory—Charles J. Gilbert, *State Weed Board,* Brookings, South Dakota
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Terminology—W. C. Dutton, *Dow Chemical Company,* Midland, Michigan
Publication—L. M. Stahler, *Bureau Plant Industry,* U.S.D.A., *State College,* Brookings, South Dakota
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PREFACE

These Proceedings of the Sixth Annual Meeting of the North Central Weed Control Conference held at Sioux Falls, South Dakota on December 6, 7, 8, 1949, present the formal papers, forums and reports of formal committees of the Conference.

The report of the Research Committee is bound separately and was distributed at the opening of the Conference. Additional copies of the 1949 research Committee Report are available at $2.00 per copy from the Research Committee Chairman, Dr. B. H. Grigsby.

Additional coppies of these Proceedings are available at $2.00 per copy from Mr. Chas. J. Gilbert, Chairman of General Arrangements for the 1949 meeting.

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Omaha

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Glenn Viehmeyer, Vice-President of N. C. W. C. Conference, Presiding

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Dayton Klingman, Bureau of Plant Industry, Soils & Agricultural Engineering, U.S.D., Lincoln, Nebraska

D. A. Savage, United States Southern Great Plains Field Station, Woodward, Oklahoma

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Presiding
Toastmaster
F. H. Leibach, President of South Dakota State College, Brookings

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Introductory Remarks

R. S. Dunham, President

I have a few minutes before the address of the morning to make a few remarks. I do not need much time since what I have to say is brief and very much to the point. It relates to the future of this organization. We have enjoyed considerable success since its birth 5 years ago. The Conference has grown in membership, meetings have been well attended, it has won a respected place, and it is financially stable. Much of this must be attributed to the glamor of 2,4-D. When the glow of the hormonetype herbicide begins to dim, what then?

The interest in weed control work that has been stimulated the last few years has been beyond anything in the past and beyond many dreams for the future. What a tragedy it would be if this interest could not be sustained. Created largely by 2,4-D, this interest must some how be transferred to the whole weed program.

I have no fear for the future of this organization in so far as it is based on technical advance. I have every confidence in the ability of the men in every phase of the weed control program in so far as it relates to the solution of problems within their field whether it be regulatory, educational, industrial, or research. What I am afraid of, as we are afraid of in the whole world, is that we can't work together. It is a tremendous paradox but true that we must divide further and further as specialists but at the same time work together as a whole. It is neither possible nor desirable in my opinion to restrict specialization. We need plant physiologists, biochemists, botanists, foresters, agricultural engineers, horticulturalists, and agronomists. We need attorneys, specialists in weed laws, specialists in seed laws, and administrators. We need speakers, writers, and public contact men. But, somehow, we must all have the same general goal.

Engineers alone could not build the Panama Canal. It took the cooperation of medical men to make possible the completion of a strictly engineering project. Somehow we must achieve what Dr. Chas. E. Kellogg calls a symmetrical science, a fitting of the parts together. Within this organization we have men interested primarily in the field of research, others in the regulatory work, others in the educational and extension areas, still others in the manufacture and sale of weed control devices. Somehow, we must realize that all are necessary to carry out a well balanced program.

I have frequently said "somehow." I believe the somehow will rest largely on organization so that team work is encouraged, on administrative officers who can preside fairly and firmly, and of course on the cooperation of all. It has been frequently said that there never can be a United Nations of Europe because of the ingrained nationalism of its people. I hope that this organization is not now and never will be composed of such independent segments that they cannot be fitted together.

The Physiology of Weed Control

A. S. Crafts

Physiology treats the application of chemical and physical principles in the study of life processes. Since the origin, maintenance, and the cessation of life are basically physiological, weed control is obviously applied plant physiology. And the action of herbicides involves physiological processes fundamental to the survival of the species involved.

My title today is very inclusive. However, because most of you are familiar with the broader aspects of weed control by cropping and cultural methods, I will confine my talk to four phases of chemical control that are developing rapidly at the present time. These are the absorption of herbicides, selectivity of herbicides, translocation of herbicides, and mechanisms of herbicidal action.

ABSORPTION

In order to understand the mechanics of absorption by plant cells, is necessary to consider the nature of the substances being absorbed, the nature of the medium in which they are carried, and the properties of the plant tissues themselves. I will start by contrasting the properties of the two common carriers of herbicides—water and oils.

Water is a very unusual liquid. Being so common, we take it for granted but chemically it is unlike most other liquids. Being composed of hydrogen, a strongly electropositive element, and oxygen, one of the most electronegative, water is extremely stable. In addition to their normal valence attractions, hydrogen has a secondary valence of plus one while oxygen has a secondary valence of minus two. Because of these residual valences, water molecules have strong forces of attraction for each other; the liquid is strongly coordinated and tends at low temperatures to assume a lattice structure.

Because the electrical charges on the water molecule are separated from each other, each molecule has a plus and a minus end; the molecules are polar. When the molecules spin they set up strong electrical force fields; the liquid has a high dielectric constant; it tends to saturate the electrical field between the ions of polar compounds such as the common water-soluble salts. This lessens the attractive forces between the ions and they wander from their fixed positions in the crystal; in other words they go into solution. For this reason, water is an excellent solvent for polar substances, common salts that dissociate in solution. Because of their strong coordination bonding forces, water molecules hydrate most ions and many molecules containing the electro-negative elements fluorine oxygen, nitrogen, chlorine, and sulfur. Some of these elements are contained in practically all herbicides.

Turning now to oils, these are of four general types: (1) aliphatic or saturated chain compounds having carbon atoms arranged in straight or branched chains; (2) olefinic chain compounds containing double bonds between carbon atoms (unsaturated); (3) saturated ring structures termed naphthenic; and (4) unsaturated ring structures termed aromatic. All

of the carbon atoms mentioned have hydrogen atoms attached to them and the compounds are termed hydrocarbons. Most oil molecules are symmetrical and hence non-polar. Oils have low dielectric constants and low surface tensions. They are mostly less dense than water; their internal structure shows random assortment of chains or rings as contrasted with the quasi-lattice structure of water. Table 1 shows some of the physical properties of water and a few oily compounds.

Table 1

Properties	Water	Methane	Hexane	Benzene
Mol. Wt.	18	16	86	78
Density	1.00	.001	.66	.88
Boiling Point	100°	-164°	68.7°	80.4°
Melting Point	0°	-184°	-95.5°	5.4°
Surface Tension	75.6		20.5	31.6
Dielectric Constant	81		1.8	1.0

Solutions are homogeneous mixtures of different ionic or molecular species. Ionizing compounds dissolve readily in water because their strong force fields are saturated by the polar water molecules; non-ionizing compounds dissolve because the mutual attractions between their electro-negative elements and the electro-positive hydrogen of water constitute bonding forces resulting in strong hydration. Examples of ionizing herbicidal compounds are sodium arsenite, sodium chlorate, sodium borate, ammonium thyiocyanate, ammonium sulfamate, sodium pentachlorophenate, the salts of 2,4-D and of trichloroacetic acid. Non-ionizing solutes are sugar, glycerin, alcohol, polyethylene glycol (Carbowax), and other cosolvents and sequestering agents of organic composition.

Oils are good solvents for oily compounds. For instance, the four types of oils mentioned above all dissolve readily in each other. Furthermore, many undissociated compounds of non-polar character dissolve in oils; such compounds are benzenes, phenols, and weak organic acids. Herbicidal compounds of this type are chlorinated benzenes, aromatic solvents of the xylene type, pentachlorophenol, dinitro substituted phenols, dichlorophenoxyacetic acid, and maleic hydrazide. The more polar of these compounds dissolve best in the more polar types of oils, that is, the unsatturated types.

Emulsions are mixtures of immiscible liquids, oils and water for example. Since almost any two liquids differ in density, such mixtures tend to separate into distinct layers if they are not agitated constanly. Emulsion stabilizers are compounds having molecules that are polar at one end and non-polar at the other. When added to emulsions these molecules arrange themselves at the interfaces between the immiscible phases. For example, when a petroleum sodium sulfonate stabilizer such as Oronite wetting agent is added to an oil-water emulsion, the petroleum ends of the stabilizer molecules dissolve in the oil droplets and the sodium sulfonate (polar) ends dissolve in the water. The oil droplets assume like electrical charges and hence repel each other; this keeps them apart; they do not coalesce, hence the emulsion is stable. Breaking the oil droplets up into extremely fine particles further stabilizes the emulsion because these very fine particles are constantly agitated by Brownian movement, the kinetic agitation of the molecules. Homogenization does this.

The virtues of an emulsion stabilizer in an oil emulsion herbicide are two-fold. The very properties that orient the molecules so that they stabilize the oil-water interface also reduce the interfacial tension and make the water more oil-like. For this reason the stabilized emulsion spreads readily over the waxy surface of the foliage, covering the weeds completely and creeping to a limited extent down into the crowns. This is a favorable distribution for a contact type of herbicide and in such sprays a stabilizer is of great value.

Plant surfaces are of two distinct types. The absorbing surfaces of the roots adapted to the function of absorbing water and mineral nutrients are composed of highly hydrated, partially dissociated pectic substances. These substances are polar in nature and they are compatible with the polar compounds that the plant requires from its soil environment. To be readily absorbed from the soil by roots, herbicides applied to the soil should be in the form of dissociable salts or as compounds that will hydrolyse in the soil. The common soil sterilants are of this type.

The remainder of the plant is covered with a protective layer specialized to prevent rapid loss of water. This is particularly true of the larger stems and roots; leaves have small openings (stomata) by which CO_2 absorption and loss of water vapor may take place under a certain degree of control. The remainder of their surfaces are covered with cuticle that restricts but may not entirely prevent loss of water vapor.

Most herbicidal sprays are applied to the leaves of weeds and in order to be absorbed into the living tissues they must penetrate the cuticle. This is a waxy coating, non-polar in nature, with a residual negative electro-static charge. Negative ions in solution are repelled by the cuticle; positive ions are attracted and held on the surface. Highly polar molecules dissolve with difficulty in the cuticle and hence are not readly absorbed; undissociated compounds of non-polar character (oil-like) dissolve and pass through readily. This is the reason that undissociated substituted phenol and phenoxyacetic acid molecules are more effective than their corresponding ions; that esters of such acids are more effective than salts.

To summarize the problems of absorption, if a weed killer is to be presented to the plants through the soil for absorption by roots it should be in a water-soluble and hence in a polar form. Colemanite, arsenic trioxide, or 2,4-D acid are not exceptions, being highly toxic they are applied as compounds of low solubility simply to prolong their release to the plants. They enter the plants in ionized form after slow dissolution or hydrolysis in the soil. The toxic vapors of CS_2, chloropicrin, and DD are not exceptions; they are all somewhat soluble in water; there is evidence that they also enter the older roots through the non-polar periderm layer. To enter, leaves must be in a non-polar form. Some chemicals diffuse on and kill plant cells; they are contact killers. Some are absorbed and translocated and the symtoms are systemic.

SELECTIVITY

I will treat the various types of selectivity briefly, trying to relate each to known characteristics of the solutions used and the plants to which they are applied.

1. *Differential Wetting.* — Because the leaves of cereals, flax, peas, young alfalfa, onions, and a number of other crop plants are highly cutinized and often corrugated or irregular on the surface, highly polar liquids such as water solutions of herbicidal salts fail to wet them, whereas certain weeds are readily wet. For best results the spray should be coarse, with ample velocity; the crop plants should not be wet with dew.

2. *Morphological selectivity.* — Plants of mustard, radish, fiddleneck, and other weeds have their growing or meristematic tissues at the tips or in their leaf axils. These can be hit by a spray. In contrast, grass plants grow from meristems located at or below the soil surface and protected by the bases of all the lower leaves. To kill grasses you need a spray of low surface tension such as an oil that will creep and penetrate down into the crown and kill the meristematic tissues.

3. *Selective spray placement.* — Because grass plants and most mature broad-leafed plants have their basal stem tissues protected by surrounding leaves or bark, it is possible to spray low in the crop with a general-contact herbicide and kill all young weeds, including grasses. Many herbicides can be used selectively this way. Examples are salts of the substituted phenols, fortified oil emulsions, straight oils, 2,4-D, TCA, maleic hydrazide, etc. Crops are corn, sugar cane, onions, cotton, flax, alfalfa, and other field crops when planted in rows. This method is very useful for controlling weeds in row crops being raised for seed.

4. *Biochemical Selectivity.* — If young barley and carrot plants are sprayed with a light aliphatic oil neither will die; if about 30 per cent of a xylene type aromatic oil is included in the spray the barley will die and the carrots remain unharmed; if pure xylene is used both plants die.

If these same two species are sprayed with 10 ppm (parts per million) of 2,4-D amine in water the carrots may twist and curl but neither plant will die. If 1000 ppm is used the carrots will die and the barley will be unharmed. If 10,000 ppm are used both species will die. These are examples of biochemical selectivity; this effect is relative with respect to concentration of the toxicant and depends upon the susceptibility of the plants involved. Because weeds and crop plants growing together constitute a mixed population of varying susceptibility to chemicals, it seems possible that eventually selective herbicides for every common crop situation may be discovered. Biochemical selectivity is the most reliable type becaues it is less subject to dosage, concentration, and environmental variables.

5. *Selective Soil Sterilization.* — Because plants exhibit varying susceptibility to toxicants applied through the soil, herbicides may be used to control weeds in growing crops. An example is the use of 2,4-D salts as pre-emergence treaments in corn, sugar cane, milo, and similar crops. Even grass seedlings have been controlled by such practice. The principal drawback is the uncertainty of rains in many regions; with no rainfall the treatment fails and with too much the chemical is leached away, resulting in poor results.

6. *Life Habit.—annuals vs. perennials.* — Selective control of annual weeds in perennial crops is often feasible if the application can be made while the crop is dormant or just after a harvest. Examples are the use of the fortified oil emulsion spray to kill winter annual grasses such as foxtail, rip-gut, and annual blue grass in dormant alfalfa during the late winter. Certain broad-leafed annuals such as mustards, radish, shepherd's purse and fiddleneck may also be eliminated. The same treatment may be made during the crop season by applying the spray just after removing a crop. This is most feasible where the alfalfa is removed green for dehydration.

In all work with selective sprays it should be remembered that selectivity is relative. For example, 2,4-D at 250 ppm may be used to kill Ribes species in the forest; no harm is done to conifers and many other brushy species. At 500-750 ppm, 2,4-D will kill mustards out of flax; and at 1000-2000 ppm it will control fiddleneck in barley and lilies in rice. At excessive concentrations 2,4-D will injure any plant, and in every situation there are definite limits of concentration between which it is safe to work. This rule applies to other selective herbicides as well and in all situations where selective sprays are used the operator must know and keep within these limits if he is to have success with the chemical. Two or more types are simultaneously effective in many cases.

TRANSLOCATION

Work with the hormone indole acetic acid, with 2,4-D, and with a number of other herbicides has proved that when these chemicals are applied in water-soluble form to the roots of plants they are absorbed and translocated through the stems to the leaves in the transpiration stream. If the concentration is adequate and the supply is maintained, toxic chemicals so used will kill the plants. Sodium arsenite, sodium chlorate, ammonium thiocyanate, ammonium sulfamate, and a host of other herbicides will move through plants in this way and accumulate in the tops, resulting in speedy death.

Furthermore, if tops of plants are emersed in solutions of these toxic chemicals, the toxicant will be absorbed and translocated through the xylem from the emersed shoots down into roots and across interconnecting roots into other shoots. This is the basis for the jar method, used to kill wild morning-glory in strawberry patches and employed by the California State Department of Agriculture in its fight against camel thorn.

Rate of absorption is not important in the jar method but very important in acid-arsenical method.

If phosphates, sugars, indole acetic acid, or 2,4-D compounds are sprayed on the leaves of plants that are moving food materials from the leaves into the roots, these chemicals may migrate across the mesophyll into the phloem and translocate into the roots along with the foods. A good many experiments indicate that such movement in the phloem is determined by the flow of the food materials in solution and not by a gradient of the applied material. For example, such movement from starch-filled leaves will take place in the dark but, from depleted leaves, light,

and presumably photosynthesis, is required. Varying the amount of 2,4-D applied had very little affect on the rate of movement in bean plants but the degree of bending of the stem was closely correlated with dosage.

There is limited evidence that certain compounds undergo polar transport in plant tissues. Sugars traversing the mesophyll may be concentrated in the phloem; indole acetic acid will move basipetally in the oat coleoptile, whereas a gradient 1000 fold greater is required to induce acropetal movement; 2,4-D applied to many plants accumulates in cambium and apical meristems where it kills the cells, whereas surrounding parenchyma survives.

There is also evidence for another type of polar movement, one determined by physical forces of the environment. For example, indole acetic acid is influenced by light to move to the unexposed side of the oat coleoptile, causing bending toward the light. Auxin in lodged grain stems is influenced by the gravitational field to accumulate at the lower side, causing upward bending. And 2,4-D applied to wild morning-glory moves downward through the tap root but may not penetrate more than an inch or so into laterals, in spite of the fact that food is moving into the laterals to supply their needs in growth and storage. Such polar movement of 2,4-D explains many of the responses one finds where this material is used under varying conditions in the field.

The transport of 2,4-D and similar substances in the plant depends upon many factors. Movement through the cuticle and intervening mesophyll into the phloem is a relatively slow process; after the chemical enters the phloem, experiments indicate that movement is quite rapid. As mentioned above, it seems to be related to food movement rather than to any mechanism depending upon the 2,4-D gradient.

Response to hormone-like herbicides depends not alone on absorption and translocation but also upon the condition of the receiving tissues; meristems respond whereas mature parenchyma does not; young roots may be killed while old roots survive. In considering field results with 2,4-D formulations some of the results are explainable on the basis of the conditions mentioned above. Field results indicate that 2,4-D esters are two to three times as toxic as the salts when used as contact herbicides on mustards in grain or on lilies in rice. However, as translocated herbicides on deep-rooted perennials, there may be little or no difference between them. On the other hand, the suspended 2,4-D acid applied in an emulsion containing just enough non-toxic oil to hold the particles on the leaves has proved superior in a number of instances. Perhaps the ester penetrates the leaves so rapidly that injury to the mesophyll and phloem prevents the required translocation. The slower moving salt would, under these conditions, move in subtoxic amounts into the roots where accumulation in the meristematic regions would result in utimate injury. The suspended acid might be absorbed and moved even more slowly, at least during the first few hours, resulting in an even greater accumulation in the roots. That the initial toxicity of the spray inhibits translocation is indicated by early experiments where 2,4-D in aromatic oil and in dinitro-fortified oil failed to kill roots of cattails where translocation was essential. The same 2,4-D dosage applied alone killed the roots of many of the plants.

MECHANISM OF TOXICITY

Problems of herbicidal toxicity are complex because many chemicals are used having various phyotoxic properties. Among the classical materials arsenic, borax, and chlorate are used in relatively large quantities; arsenic is a protein precipitant, boron causes chlorosis and chlorate, antagonizing nitrate, causes chlorosis and nutritional deficiency and death through nutritional disturbance. As sprays they are required at rates of several pounds per acre; through the soil several hundred pounds may be necessary. H_2SO_4 —corrosive to plant cells.

Toxicity of oils seems related to two properties, the size of the molecules, as this determines volatility, and hence exposure time, and the degree of unsaturation. Saturated (aliphatic and naphthenic) hydrocarbons are relatively low in toxicity; olefins and aromatic hydrocarbons are more toxic.

Starting with a series of aromatic hydrocarbons, toxicity is found to increase with increasing numbers of straight alkyl substitutions; for example, the series benzene, toluene, xylene, mesitylene exhibits such properties. These non-polar substitutions render the benzene more oil-like and probably enhance its penetration through the cuticle.

In contrast, polar substitutions also increase toxicity; phenol is more toxic than benzene, and chlorine substitutions increase toxicity of phenol up to the penta form. Nitro groups also increase phenol toxicity. Various polar and non-polar groups may be placed on the phenol molecule to produce such a compound as dinito-ortho-secondary butyl phenol, the most toxic, non-hormone molecule in common use as a herbicide. In this case increase in molecular weight gives a molecule that will not volatilize; exposure time is prolonged. Non-polar groups such as the butyl chain make the molecule oil-like; it readily penetrates the cuticle. And the polar nitro groups render it very reactive; it destroys the protoplasm when present only in minute amounts.

Of great interest is the toxic nature of the herbicides that act in small amounts; the dinitro compounds I.P.C., maleic hydrazide, 2, 4-D, etc. Apparently these compounds work through enzyme systems in plants, disturbing growth and metabolism and eventually killing the tissues.

If introduced directly into the stomach of a sheep, dinitro compounds bring about a rapid rise in temperature, resulting in death. The same amount of chemical sprayed upon green vegetation and fed to the aminal causes no disturbance. Evidently these very reactive compounds are altered during their contact with plant cells in such a way that they no longer cause their typical response in the animal. Possibly their role is to uncouple the processes responsible for normal energy transfer in cells, resulting in a rapid and destructive dissipation of the available reserves.

I.P.C. is the isopropyl ester of phenyl carbamic acid. Urethans, the ethyl ester of carbamic acid, is an antipyretic and an inhibitor of photosynthesis. Other esters of carbamic acid are known to have sedative and hypnotic properties. It is interesting that I.P.C. should have growth inhibiting properties, particularly

on roots, and that it should be specific for certain grasses.

Maleic hydrazide has a heterocyclic ring structure with four carbons and two nitrogens in the ring; it has two double bonded oxygens that should be fairly reactive. Maleic hydrozide is a strong growth inhibitor; on sugar beets, cotton, and tomato it causes malformation of leaves; on tomato and flax, axillary buds are induced to expand. On young tomato plants concentrations 0.2 percent and above cause anthocyanin pigmentation and stunting resembling curly-top infection. On older tomatoes, shoots, both terminal and axillary have symtoms resembling shoestring virus. On grasses growth is inhibited; old leaves turn yellow and die. At sublethal concentrations grass plants are stunted, tillering is stimulated and maturity delayed.

Much speculation as to the mechanism of toxicity attends the herbicidal use of 2, 4-D. Van Overbeek has proposed that because 2,4-D resembles auxin it is absorbed into leaves where it may combine with protein to form an auxin-like enzyme capable of splitting high-energy phosphates into inorganic phosphate with release of energy. As this occurs there is increased respiration, hydrolysis of starch, and a general depletion of food reserves. Olsen, working at Davis, has found a reciprocal relation between root growth and phosphatase activity with increasing 2,4-D concentration in the medium.

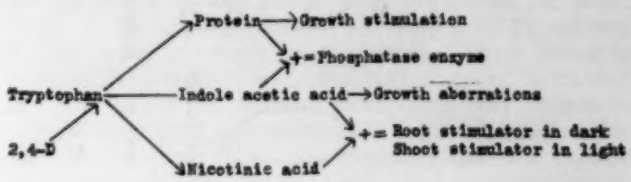
Paatela has proposed that 2,4-D supplements the natural auxin in plants. As a result normal plants treated with 2,4-D develop an excess which proves toxic, whereas weak or shaded plants acquire a more normal supply and hence are stimulated.

Considering the physiological responses of both stimulation and repression of growth depending on concentration, and the great array of morphological responses observed, it seems that these theories of 2,4-D toxicity are too simple.

Bonner and Wildman have suggested that tryptophan may undergo two fundamental transformations, one to a protein, the other through indole pyruvic acid to indole acetic acid. If 2,4-D could be shown to affect the equilibrium between tryptophan and these two products a broader interpretation presents itself. If protein is favored, stimulation of growth might result whereas increase in auxin might cause the variety of morphological aberrations observed.

Galston has recently pointed out a third product that might come from tryptophan, namely nicotinic acid. He shows that nicotinic acid and indole acetic acid in the dark favor root initiation, while in the light they favor shoot growth.

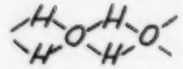
Could it be possible that the two above schemes could be combined into a more complete picture as indicated by the following diagram?



If 2,4-D should affect the above transformations, increase in protein might explain the growth stimulation of cotton shoots, grape tendrils, and many seedlings found in the light and that of root growth in the dark. Increase in indole acetic acid might bring about the morphological aberrations so commonly observed in 2,4-D treated plants. And in proper combination indole acetic acid plus nicotinic might stimulate root initiation and growth, as observed on treated plants. On the other hand, a favorable combination of protein and indole acetic acid might result in increased phosphatase which in turn would account for depletion of stored food. Such a combination might explain the stimulation found from low application of 2,4-D, the translocation, accumulation in, and death of meristems from intermediate dosage, and the immediate contact killing and restricted translocation resulting from heavy application of the readily absorbed esters.

DIAGRAM AND ILLUSTRATION ON PAGE 14

Water molecule Secondary valence forces

Lattice structure 

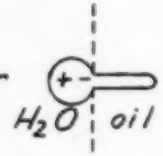
Polarmolecule

Oils 1. Aliphatic C-C-C-C Carbon Chain

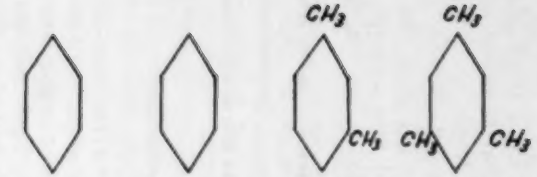
2. Olefinic C-C=C-C

3. Naphthenic Saturated Ring

4. Aromatic

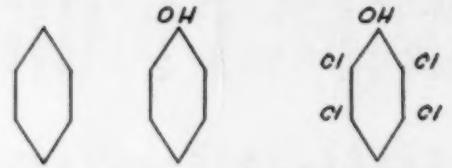
Stabilizer  Emulsion droplet

Selectivity - Take from selectivity, circular



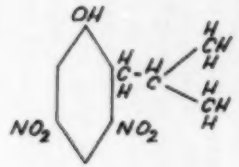
Benzene Toluene Xylene Mesitylene

Toxicity series → Increasing toxicity

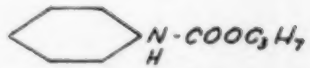


Benzene Phenol Pentachlorophenol

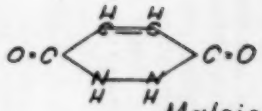
→ Increasing toxicity



Dinitro secondary butyl phenol



I. P. C.



Maleic Hydrazide

Control of Annual and Winter Annual Weeds

A. H. Larson

The control of annual and winter annual weeds is one of the major economic phases of the farm problem. Annual types of weeds are well adapted to maintain themselves and to compete successfully with a large number of farm crops. Some of the characteristics that make them so successful are: ability to produce large quantities of long lived seeds in short growing seasons, seeds that are difficult to seperate from accompanying crop seeds, ability to adjust to the growth habits of farm crops and the ability to live in a wide variety of soils under various weather conditions.

Any remarks made will pertain to post-emergence applications of chemicals, as pre-emergence applications will be discussed at another time. Chemical weed control is now a well established phase in farming, especially in controlling susceptible broad leaved weeds in small grain crops and will continue to increase as progress is made in developing new chemicals and in devising better technique and facilities in making the applications. At present there seems to be a gap in information regarding the physiological effects of the chemicals, especially of the 2,4-D products, upon the living processes of the plants concerned. The material herein considered was received from several sources and from widely separated areas, from Nova Scotia to Kansas. The methods of applying were not always the same nor evaluation of the results made upon the same basis. Most of the interest was centered around the use of 2,4-D in different formulations in controlling broad leaved weeds in cereal crops. Some work was done with 2,4,5-T, the dinitro compounds, tri-chloroacetate, penta chlorophenol, cyanamid and several products of the American Chemical Paint Company, which were designated by number.

Of first importance in the use of the 2,4-D and similar formulations is the time of making the applications. Starting with the 2 to 3 true leaf stage of the weed seedling and continuing up to the stage where seeds were beginning to develop, there was a progressive reduction in the effectivness of most of the chemical formulations, and especially of the 2,4-D compounds. Minimum amounts of chemicals, needed to produce similar results, increased. Best results were gotten when the applications were made in the 2 to 3 true leaf stage of the weed seedlings. Almost equal results were gotten when applications were made in the following rapid vegetative stage. There was a decline in the effectiveness, in the early blooming stage and some recovery in the full blooming period. In the seed development stage, seeds sometimes went on to maturity. This indicates that the time of making applications is important and that an effort should be made to do spraying of 2,4-D at that time.

In some areas weather conditions were unfavorable for rapid growth, especially in the early part of the growing season. This evidently lowered the effectiveness of the 2,4-D formulations as compared with that, where growing conditions were favorable. Lack of moisture was most often mentioned as being a limiting factor. A thin growth of crop plants was favorable for the growth of weeds. The weed plants needed heavier applications of 2,4-D to produce comparable results. When crop yields were the basis for evaluating the effectiveness of the chemical, an increase was thought to be due to the lessening of weed competition, rather than to any possibility of chemical stimulation to the crop plant.

Most of the reports submitted were with the use of 2,4-D and 2,4,5-T either alone or in combination with each other or with tri-chloroacetate or penta chloro-phenol. The amounts applied varied from 2 ounces of 2,4-D acid per acre to one pound per acre. Most of the applications varied from 4 to 12 ounces. A few were as much as 3 pounds. Better controls were usually gotten with the higher rates, 8 ounces per acre being the amount most commonly satisfactory. Nearly all applications with growing crops were made in oats and flax. In some cases they were made in solid stands of weeds alone. When comparisons were made of the different formulations of 2,4-D, the esters were reported as being the most effective, followed by the amine and then the sodium salt. When used alone, 2,4,5-T was reported as being no more effective than the sodium salt. Most applications of 2,4-D and 2,4,5-T were made in 4 to 10 gallons of water per acre. The dinitro compounds were applied in 100 gallons of water per acre. Tri-chloroacetate was applied in water. Where more than 8 ounces of 2,4-D per acre were used, the yields of crops were often reduced. To eliminate the second year rosette stage of Arctic sweet clover, 8 ounces of butyl ester at the 6 to 12 inch stage of growth was effective. Later stages were marked by extensive regrowth from the crown. Sodium tri-chloroacetate was used in several instances in attempts to control wild oats and green foxtail. Amounts up to 48 pounds per acre gave no control of these weeds but did cause injury to the accompanying flax. When mixed with ¼ pound of 2,4-D at the rate of 12 pounds per acre of tri-chloroacetate there was excellent control of lambs-quarters and kochia. When applied at the rate of 40 pounds of T.C.A. per acre in water plus 16 pounds of penta chloro-phenol in water or 8 pounds of penta chlorophenol in oil there was a large reduction in the flax stand with no appreciable reduction in the weeds. These results do not appear to be promising for the use of tri-chloroacetate and penta chlorophenol in the control of weedy grasses in flax fields.

One trial was made to compare the effects of a volatile ethyl ester and a non-volatile ester of 2,4-D at the rates of 2 and 6 ounces per acre in the control of stinkweed or frenchweed, Russian thistle, wild buckwheat and pigweed. Young tomato plants, set out in definite placing, immediately after the sprays were applied, were used to check the effects of vapors in the air. There was no injury to the tomatoes in the non-volatile trial while in the case of the volatile ester there was extensive twisting of the test plants in 2 hours after being set out. There was excellent kill of weeds with the exception of the buckwheat.

Dinitro compounds were effective in controlling weeds in red clover seeded with an oats crop. Appli-

cations were made at the rates of 1½ and 3 quarts per acre in 100 gallons of water in fields infested with wild radish and lamb-quarters at the time the oats was heading. There was no injury to the red clover. Similar results were gotten with amine salt and sodium salt of 2,4-D when applied at the rates of 4 and 8 ounces per acre in water and with cyanamid special grade (dust) at the rate of 100 pounds per acre.

In making this report on the material submitted, it is obvious that there is a lack of uniformity in the procedures followed in doing the experimental work and evaluating the results. This adds much to the difficulty of trying to summarize the results and to make proper deductions from the various reports. It would seem pertinent that it might be well to formulate a more or less standard procedure, that could be modified to fit local conditions, for conducting the experiments having to do with annual weed control; that all doing such work be furnished with a copy of such procedures. It would simplify the work and make it possible to better evaluate each of the factors concerned with the results obtained.

A list of relative susceptibility of some common annual and winter annual weeds, is included here, but I shall not burden you with a recount of them, hoping that they may appear in the proceedings.

A list of weeds and their susceptibilities follow: Plants killed by 2,4-D formulations in quantities of 4 to 8 ounces per acre in the early seedling, prebud and early blossoming stages are considered as being susceptible. Those killed in the first two stages but not in the third are considered as being intermediate, while those not killed in the first stage are considered to be resistant in this evaluation.

SUSCEPTIBLE:

Abutilon theophrasti
Acalypha virginica
Amaranthus blitoides
Arctium minor
Brassica arvenses
Brassica juncea
Camelina microcarpa
Capsella bursa-pastons
Erigeron ramosus
Martynia louisiana
Matricaria matricaroides
Monolysis nuttalliana
Vicia angustifolia
Neslia paniculata
Ranunculus arvensis
Raphanus Raphanistrun
Sisymbrium incisum
Sisymbrium Sophia
Tribulus Terrestrix

INTERMEDIATE:

Acnida tamariscina
Amaranthus retroflexus
Ambrosia artemisiifolia
Ambrosia psilostachya
Ambrosia trifida
Atriplex species
Chenopodium album
Conringia orientalis
Dipsacus sylvestris
Erigeron canadensis
Erysimum cheiranthoides
Helianthus annuus
Hibiscus trionum
Iva xanthifolia
Kochia scoparia
Lappula species
Malva rotundifolia
Polygonum aviculare
Potentilla monspeliensis
Salsola pestifer
Sida spinosa
Thlaspi arvense
Xanthium species

RESISTANT:

All grasses
Agrostemma Githago
Cannabis sativa
Croton monanthogynus
Daucus Carota
Fumaria officinalis
Lactuca scariola
Lamium amplexicaule
Lepidium virginicum
Physalis pubescens
Polygonum Convolvulus
Polygonum Persicaria
Portulaca oleracea
Saponaria Vaccaria
Silene species
Solanum nigrum
Spergula arvensis

Perennial Weed Control

H. E. Wood

Most troublesome of the perennial weeds met with in crop production in the Great Plains area are the following: Quack Grass, *Agropyron repens;* Canada Thistle, *Cirsium arvense;* Perennial Sow Thistle, *Sonchus arvensis;* Field Bindweed, *Convolvulus arvensis;* Leafy Spurge, *Euphorbia Esula;* Hoary Cress, *Cardaria Draba* and others; Russian Knapweed, *Centaurea repens;* Bladder Campion, *Silene latifolia;* Toadflax, *Linaria vulgaris;* Poverty Weed, *Iva Axillaris;* Hedge Bindweed, *Convolvulus sepium;* Horsetail, *Equisetum arvense.* All but the latter three, which are probably the least serious, have been introduced from Eurasia.

Perennial weeds, in contrast to annual weeds, differ in at least two main respects: (1) they are usually less uniformly dispersed throughout a field or on noncultivated land. (2) they usually offer more resistance to control measures. Successful eradication depends upon measures that bring about starvation of the plant by exhausting the often large food reserves stored in the plant's deep and extensive root system. Short cuts to eradication in some instances lie in attacking the plant at a time immediately following the period when food reserves have been partially depleted.

As eradication (or control) may employ tillage and cropping practices as well as the use of herbicides, both will be discussed briefly:

Intensive Cultivation Supplemented by Cropping

The infestation of any species of perennial weed or the combination of several, where found on arable land, after having passed the small and scattered patch stage can, under most circumstances, be most effectively and cheaply eradicated by intensive cultivation alternated with cropping. The persistance of the weed—field bindweed, leafy spurge, and hoary cress, serve as typical examples of weeds that are very persistant—will determine the number of years control measures will require to be carried on. Based upon ten years' experience in Manitoba with a Government-Municipal project, in which several thousand acres of land have been freed of leafy spurge, I have no hesitation in commending this method of control. Regular and thorough tillage alternated with planting to quick growing crops of a kind that shade the land, harvest early, and permit tillage to be renewed in early fall, carried over approximately a five-year period, will free land of the most persistant perennial weeds. Furthermore, the returns accruing from the crops, grown during the years eradication is under way, will in most cases meet or be in excess of operating expenses. More attention can well be directed to intensive cultivation as the first and most practicable

method of eradicating perennial weeds from arable land.

Canada thistle differs from the aforementioned group in that it will withstand very considerable cultivation. However, control, and at times complete eradication of the weed, is obtained by seeding down infested land to alfalfa, a crop with which Canada thistle seems unable to compete. The less persistent weeds, of which quack grass serves as an example, under favorable conditions can usually be eradicated in one season of intelligent and properly directly tillage.

It is not within the scope of this paper to discuss the many angles to tillage and cropping practices that this method of weed control raises. The great range of soil types met with in the area served by this Conference, soil erosion problems common to a given area, tillage implements available or suitable, etc., all have an important bearing on the problem. Likewise the choice of crops that fit into such a system of intensive cultivation are dependent upon local conditions. Of paramount importance is a tillage job regularly and well done over a sufficiently long period to starve the root systems of the weeds, with the cropping supplemental to the tillage.

Lest there be any misunderstanding as to the important place grasses and legumes have in weed control, a comment at this point seems advisable. Where systematic crop rotations, which include grasses and legumes, are routine farm practice weeds seldom are a serious problem. Faced with eradicating perennial weeds from polluted land under tillage grasses and legumes, by providing competition for the weeds, will be found helpful whether eradication be by cultural methods, the use of chemical, or both.

Chlorates and Borax

With the introduction, about twenty-five years ago, of sodium chlorate (also the trade product Atlacide) and, more recently, borax compounds, marked headway has been made in eradicating certain of the perennial weeds. These two chemicals are classed as soil sterilants, in that they render the soil sterile until leached out some years after application. Their relatively high cost has confined their agricultural use mainly to the group of deep-rooted persistent weeds before they have spread beyond the small and scattered patch stage. Where properly applied, with the necessary follow-up in succeeding years, these chemicals have been effective in checking the spread of weeds that, in many instances, could not have been handled otherwise.

The Hormone or Systemic Herbicides

With the introduction of the hormone or systemic herbicides the expectation and hope was that here was a chemical without the objection of soil sterility, and at the same time relatively cheap, which could be used against perennial weeds. Early trials soon indicated that most perennial weeds showed an even greater variation in response to 2,4-D than did annual weeds. It is now agreed that the resistance of perennials to 2,4-D ranges from very susceptible to, in a few instances, species that are highly resistant even at heavy doses. To obtain eradication, or reasonable control of susceptible perennial weeds, repeated applications over several years are required for other than those species that are quite susceptible.

Perennial weed control by the newer chemicals presents two approaches that differ markedly; namely, (1) control when met with in growing crops; (2) control on land under cultivation and on non-tilled land. Both will be discussed briefly, following which each of the more common perennial weeds will be discussed in their response to the hormone herbicides.

Control of Perennial Weeds in Growing Crops

The use of 2,4-D in growing crops infested with perennial weeds is proving of far-reaching value. Control, rather than eradication, is obtained by such treatment, thereby removing or greatly reducing the hazard such weeds would be to growing crops. Harvesting operations are made easier by removal of weed growth. For such treatment the esters have a preference. An exception to this generalization arises in sections where the crop under treatment has seeded with it legumes (or grasses) which are more tolerant to amines than esters. Dosage recommeneded hinges around one-half pound acid per acre, or about the maximum that can be safely used on the crop being treated. While early treatment is preferred for annuals, most perennials are best treated after having passed the rosette stage, otherwise, although killed back to the ground, new growth quickly reappears. Time of treatment, however, will depend to some extent upon the stage of crop growth, as most crops are better to have perennial weeds set back before the crop reaches the boot stage, rather than after heading is completed. Weeds that respond particularly well to this method of treatment include Canada and sow thistle, bindweeds, and leafy spurge.

Control of Perennial Weeds Other than in Growing Crops

The substitution of herbicides for tillage to control perennial weeds on land under cultivation offers advantages, such as reducing the cost, lessening the hazard of soil erosion, etc. On infested land not being tilled it may be the only means of attacking the weed problem. Evidence to hand, even when the more susceptible perennial weeds are considered, indicates no over-all recommendation can be made for widespread use of 2,4-D and similar products with the expectation of obtaining complete eradication. Where the more susceptible species are met with on land in grass re, peated applications of 2,4-D in dosages from three-quarters to one pound of acid per acre will greatly reduce the weed stand, thereby allowing the grass to re-establish. In general the treatment with chemical of perennials when not in growing crop should be made when the plants have reached the bud to early flower stage; less satisfactory results follow early spring or late fall treatment.

Limited trials conducted this past season indicate possible variations from the above recommendations: (1) the combination of tillage practices and the use of chemical; (2) the application of relatively high dosages of 2,4-D (from 2 to 4 pounds acid per acre rather than around one pound) to certain of the persistent perennial weeds. Data to hand are insufficient to more than mention these approaches and the possibilities they may offer in the future.

Quack or Twitch Grass — The indroduction of sod-

ium trichloracetate (TCA) has offered interesting possibilities with this troublesome and widely spread weed. Reports of trials available to the writer would suggest use of this chemical, for the present at least, will be confined to "spot" treatment of small and scattered patches, rather than wide-scale field use, cost being the limiting factor.

Where from 80 pounds upward of acid per acre has been applied to the grass under favorable growing conditions, complete, or nearly so, eradication has been obtained. Lower amounts while checking the stand have failed to eradicate the weed. Experiments have been conducted this past season in which cultivation to expose the running root-stocks of the weed has been followed with application of TCA to the soil and exposed roots. Indications point to the possibilities of using considerably lower quantities of chemical through this method.

Canada Thistle — This weed so commonly met with in cereal crops is being successfully controlled with 2,4-D. Treatment should be made getween the late rosette and early pre-bud stage using about the maximum dosage the crop will permit—this will be from 5 to 8 ounces acid per acre, or thereabouts. Treatment under these conditions will largely check the development of the weed to a point that few flowers will form; at the same time the growing crop has been freed of competition of thistles and harvesting is facilitated. If treatment is too early regrowth quickly reappears; if delayed to the bud-flower stage a higher dosage is required; the crop also suffers more weed competition.

Eradication of Canada thistle from land under grass or elsewhere is meeting with only partial success, moreover results obtained have not been very consistent. Treatment made when the thistles are in the bud-flower stage with around one pound acid per acre will usually bring about a marked reduction in stand, especially where the thistles have aggressive competition from grass. Late season treatment has been quite disappointing. Repeat applications over two or more years are usually necessary to obtain a high percentage reduction in stand. The use of 2,4,5-T has not proven as satisfactory as 2,4-D; TCA has been quite ineffective.

Perennial Sow Thistle — In comparing the response of this weed to Canada thistle when under treatment with 2,4-D a marked difference is to be noted. While both react similarly when control is sought in growing crops, perennial sow thistle is more easily eradicated when found in well established stands, especially if in active competition with grass. Dosages, period to treat, etc., are similar to those outlined above under Canada thistle so will not be repeated.

Field Bindweed — Satisfactory control of this weed can be obtained by treating with 2,4-D. Complete elimination, however, seldom occurs even when applications are repeated over several years. Favorable growing conditions and abundant top growth at the time of treatment are essential for effective results. Chemical treatment is more effective when used in combination with an aggressive competitive crop such as perennial grass. There appears to be no significant difference in the ultimate effect of the different formulations of 2,4-D on bindweed after repeated treatments, although greater reduction in stand may be obtained by the esters from the first application. Dosage of one pound acid per acre, or thereabouts, seems just as effective as higher amounts of chemical. Where control in growing crop is sought the maximum dosage that can be used on the crop in question will govern. The substitution of oil for water, or 2,4,5-T for 2,4-D offers no advantage.

Leafy Spurge — After five seasons in which trials running into the hundreds have been conducted with this weed over a wide area, 2,4-D, 2,4,5-T, and mixtures of these were used, we have nothing very conclusive to report. Top growth at almost any time is quite susceptible to any of the formulations of 2,4-D with from 4 to 8 ounces acid per acre upward. 2,4,5-T has proven even less satisfactory than 2,4-D. The problem seems to be that of translocating the chemical or its effect to the root system of the plant.

On limited trials where leafy spurge has been treated in the pre-bud to bud stage in crops using from 4 to 8 ounces acid per acre the weed has been checked, but by harvest has usually reappeared.

In turning to the eradication of leafy spurge the most promising results have followed where the weed growing in competition with grass has been treated with 2,4-D over a period of several years. From a field project in Manitoba, carried on since 1947, the following conclusions have been drawn—this would seem to be about where we should like to leave the subject: (1) The stand of leafy spurge on all treated plots has been markedly reduced with grass taking over; on the plots treated since 1947, the reduction in spurge was estimated to be 80 per cent; for 1948 plots 60 per cent; about 25 per cent regrowth was showing on the 1949 plot sprayed in June. (2) There appeared to be little difference in formulations or rates; three-quarters of a pound acid per acre plots sprayed for the first time in 1949 showed no more regrowth than had the 1947 plots treated at 2 and 4 pounds, and checked as to regrowth as the end of that season. (3) Leafy spurge seems to respond most satisfactorily to 2,4-D treatment when the plant is in full flower; one treatment in mid-summer gave comparable results with two treatments in a season. (4) While a marked reduct ion in stand of leafy spurge is obtained, there seems little likelihood that eradication of this weed is possible with 2,4-D.

Hoary Cress — The limited number of trials reported and the rather conflicting results obtained from the use of 2,4-D on this weed, which has been notoriously difficult to eradicate by means of herbicides, leads one to be hesitant with recommendations. Like most other perennial weeds, when treated in competition with grass, elimination is more easily obtained than on cultivated land. Repeated applications, at least two per season for two seasons or longer, with a dosage nearer two than one pound acid per acre, with a preference for the ester, seems to give the highest measure of control, and occasionally complete elimination.

Russian Knapweed — Limited trials that show somewhat conflicting results make it difficult to appraise the value of 2,4-D on this quite persistent weed. Under favorable growth conditions, with the plants in bud stage, dosages of from 2 to 3 pounds acid per acre have given almost complete eradication, especially where repeat applications have been made. The amine has

proven equally as effective as the ester; 2,4,5-T in combination with 2,4-D was decidedly less effective.

Bladder Campion and Toadflax — Little if any headway has been made in the control of these two weeds by the use of 2,4-D. While the top growth of bladder campion can be killed back by treatment, toadflax is proving quite resistant even in this respect.

Poverty Weed — Limited trials on this weed have given conflicting results. The Swift Current Saskatchewan Experimental Station summarizes the situation as follows: "One plot which was treated during an active period of growth with 32-ounce acid equivalent did not show any regrowth. Other plots treated at lighter rates or later dates failed to give an appreciable degree of control."

Wild Morning Glory — Limited trials, and at least two species which react somewhat differently, make it difficult to be too conclusive in reporting on this weed. Convolvulus sepium, the more common species, appears quite susceptible to 2,4-D. The americanus species met with in the drier soil areas more nearly resembles field bindweed in its reaction to treatment. The Experimental Station at Swift Current, Saskatchewan, regarding treatment of the latter species, reports: "A 4-ounce application was used, with both amine and ester formulations. This rate had formerly proved ample for a good kill of top growth with slow recovery. This year (1949) the kill was slow, and regrowth started within two weeks. The field was retreated at the same rate and the second treatment was apparently quite effective."

Horsetail — Trials with this weed, which is most troublesome in certain low-lying soils, appears to have been confined to Manitoba during 1947 to 1949. Heavy stands of horsetail on land being summerfallowed in 1947, when treated with 2,4-D in mid-August, were not controlled nor was the stand noticeably reduced. During the last two seasons the weed has been controlled when treated in early June in cereal crops. The measure of control obtained has increased as the dosage was increased; while in 1948, as low as 4 ounces acid of ester gave 90 per cent or better eradication, it required 8 to 9 ounces to give the equivalent in 1949. This weed has responded much better to an ester than an amine.

Pre-emergence Control of Weeds in Field Crops

C. J. Willard

By pre-emergence use of chemicals, we have come to understand applications made before the crop and/or the weeds emerge. There are two general types of pre-emergence: contact pre-emergence, in which weeds which have germinated before the crop emerges are killed by some general contact spray; and residual pre-emergence, in which herbicides are sprayed on the soil to kill weed seedlings at or before emergence.

Perhaps no type of chemical weed control gives such outstandingly satisfactory results as a successful pre-emergence treatment. We have had essentially perfect weed control, without damage to the crop, following treatment with several different chemicals, in corn, soybeans, and sugar beets, among field crops. Unfortunately, we have also had serious to total losses with the same crops and chemicals, following pre-emergence treatments. But, with almost perfect examples to lure us on, we feel bound to keep trying to learn if possible how to duplicate them with certainty.

There are reported this year at least 30 abstracts of experiments on the pre-emergence use of herbicides on field crops, including corn, wheat, oats, soybeans, sugar beets, canning peas, flax, and single tests with several other crops.

Geographically, the reports extend from Nova Scotia and Ohio to Nebraska and Alberta. At least 15 or 20 different chemicals are reported on. With this tremendous variation in soil, climate, crops, and materials, it is not too surprising that results appear confused.

Clearly, this review can give few, if any, definite recommendations. Can we draw any general conclusions?

First of all, it seems clear that pre-emergence sprays are the more successful, the more nearly they approach contact pre-emergence. There are many successful contact sprays, and if a spray can be timed to find the weeds up and the crop not yet through the ground, it is most successful. In all time-of-application studies the applications just before the crop emerges, or comes within killing range of the chemical, are most effective. Even 2,4-D, which has more residual effect than most sprays, has been more effective when applied just before crop emergence than when applied on the date of planting. It is not easy, in practice, to work this out in humid regions. The favorable periods for application are very short, usually only one, two, or a few days, so that a rain can completely interfere with proper timing.

Furthermore, many crops come as fast or faster than the weeds, so simple contact weed-killers will not give results on such crops, unless the planting can be done in undisturbed soil. The soils in this region are often not adapted to planting one to three weeks after their final preparation, so that the practicality of this is in serious doubt.

The pre-emergence spray most used on grain crops has been 2,4-D. An outstanding feature of the results with 2,4-D pre-emergence is their dependence on rainfall. For the best results with 2,4-D pre-emergence, the favorable moisture situation is one which permits rapid germination of both weeds and crop, but with insufficient rainfall to carry the 2,4-D down to the crop seed. If rain comes between the application of the 2,4-D and the emergence of the crop it may be killed, whether it is corn, wheat, or soybeans. If the surface soil is very dry, so that the 2,4-D does not move down at all, weeds may come from below it and establish themselves, and may not be killed when rain does come.

Consequently we must recognize that pre-emergence treatments with 2,4-D do not give satisfactory results in dry climates or seasons, and are likely to cause crop damage on many soils if rain immediately follows the treatment.

The effect of rain is modified by soil type, and so the soil type has much to do with the safety of pre-emergence treatment, especially on corn. Open, sandy

soils are dangerous for pre-emergence treatments with 2,4-D. Treatments on soils with a high organic matter content are much less hazardous than on those low in organic matter. Those on silt loams, silty clay loams and clays are less hazardous than those on light soils. Applications on well-limed soils or soils of high pH are less hazardous than those on soils of low pH.

On any soil, the dose should be the minimum dose which will accomplish the result. This minimum dose will be higher on soils of high organic matter content than on low organic matter soils.

What then can we recommend in the way of chemical weed control by pre-emergence applications? Very little except in specific tried situations. So far as we can see corn is the only field crop in which 2,4-D may be given a limited recommendation on silt loams or heavier soils of reasonable organic content. The rate should be at least one pound per acre and not over two. This is the only 2,4-D application which will affect annual grass weeds in corn. The application should be made as late as possible before the emergence of the weeds. Even if the corn has just emerged at the date of application, it will not be injured as much as by earlier applications, frequently not at all.

The proportion of successes with pre-emergence 2,4-D on corn is sufficient to recommend its trial on the soils just described where there is a serious weed problem. In general, it has been possible under these favorable condition to eliminate all but one cultivation—one cultivation, at least, has always been eliminated. It does not seem desirable to recommend eliminating all cultivations, because some soils require it, and some weed species will always escape killing and need cultivation to control.

Another successful type of pre-emergence treatment in corn is a spray of 1 to 2 pounds of 2,4-D per acre on the soil and just the bases of the corn stalks just after the last cultivation. In very weedy fields, this may prevent the corn from at once growing up to weeds after it is laid by.

Pre-emergence treatments in sugar beets will be discussed by Dr. Helgeson.

Successful pre-emergence treatments of weeds in soybeans by 2,4-D, PCP, several dinitros, and several other herbicides have been reported. The most successful herbicide when rain does not follow treatment until after emergence of the beans is 2,4-D, but the hazard is so great that 2,4-D should be kept out of the soybean field. The others are promising, with some almost sensational results, but no one of them can be safely recommended at present.

We must realize that there are a great variety of factors affecting residual pre-emergence sprays that do not affect selective and contact pre-emergence sprays. Consequently, they require especially careful checking before they are generally recommended. Let us especially beware of basing recommendations on one year's favorable tests. This is easy to do. Many chemicals have given sensational results in single, or single season, tests.

What is especially needed is to get at the principles undelying residual pre-emergence effects. This will require studies of the movement of the chemicals in different soil types under different moisture conditions; of the interactions of soils and herbicides; of the exact time and conditions under which the weeds or weed seeds and crops or crop seeds are killed. With so many variables we must be content to make haste slowly. The alternative is severe losses.

Results with Newer Herbicides in 1949

W. C. Dutton

This discussion is based on the abstracts on the newer herbicides which came to me as a member of the Research Committee of this Conference and to some extent on other information which was available. In connection with the abstracts on new materials, I would like to indicate that I am confident that much work on these new materials was done in 1949 which was not reported to me in the form of abstracts or simply was not reported at all. The failure to get abstracts to me was undoubtedly due to the fact that everything that came to me was a duplicate of what went to some other project leader and it may have been easy to forget the indicated duplication of abstracts for all work on new materials. The failure to make any report at all was due in most cases, I think, to the impossibility of finding enough time prior to November 1 to get all experimental results into a form that could be reported. Another condition that had a bearing on failure to write abstracts was that some materials were so "no good", as one man told me, that he did not write a report. These failures to get such information together is unfortunate because cooperators need positive results to guide them in planning work for 1950 and they need negative results just as much to avoid doing needless work with poor materials.

Abstracts on 27 so called new herbicides were received under Projects VII and VII-2. Many of these were reported as chemical compounds but others under code numbers only and unless I had definite information on the active ingredient they are listed simply as code numbers. This may have resulted in some 2,4-D materials being discussed as new herbicides. The results reported have been summarized under Projects VII and VII-2. Speaking of summarizing results prompts me to say that if any of the gentlemen who supplied abstracts on the use of TCA for the control of quack grass would like a little interesting past time I will suggest that you take your 1949 Research Committee report, turn to Project VII, read the reports on quack grass control with TCA and see if you can develop a logical, reasonably simple system of comparing results.

I will now try to give you a general indication of the limitations and possibilites of these materials. An attempt will be made to group similar materials, but since I do not know the active ingredient in several cases such materials will have to be listed arbitrarily.

Several *petroleum products* were used for various purposes. *Diesel* or *fuel oil* was valueless as a preemergence treatment on sugar beets and at heavy rates gave only partial control of quack grass. *Kerosene* gave excellent control of crab grass seedlings and *Stoddard solvent* gave complete kill of a heavy stand of crab grass. Two petroleum fractions, L-2687 and L-2988, were used in several trials for crab grass control with variable results. They seem to have the ability to kill the grass or to stop growth and to suppress

seed formation without injury to desirable grass species. L-2988 is probably better than L-2687. Two other materials, S-1980 and S-1998, which I understand are fortified petroleum products gave fair to good results on crab grass without injury to blue grass.

Other crab grass treatments included *PMA* (*phenyl mercury acetate*) which gave variable results from poor to complete but with considerable injury to blue grass and two other unidentified *organic* mercury compounds gave promising results. *Potassium cyanate* killed crab grass if enough was used. Blue grass was usually injured but recovered. *TCA* at low rates killed crab grass with some injury to blue grass which injury soon disappeared.

Xanthogen disulfide was reported for pre-emergence treatments on flax, soy beans, sugar beets, canning peas, and corn. Some of the reports are very indefinite but no favorable data on weed control was given. *Dichloral urea* (XP-39-A) gave some control of brome grass at heavy rates and as a pre-emergence treatment on sugar beets gave no control of broadleaved weeds, some control of grass and reduced the stand of beets. *IPC* (isopropyl-N-phenylcarbamate) gave no favorable indications against quack grass and in sugar beets as a pre-emergence treatment caused no injury and gave no weed control (species not indicated). In alfalfa it controlled several grassy weeds with some injury to 3-5 in. high alfalfa. Other results indicate value only at high rates (8 lb. or more).

Some of the coded, unidentified materials are grouped here. K-1131 is promising with fair control of weeds and grasses with no injury to alfalfa. EC3441 gave no control of quack and *7BD* was only slightly effective against quack. *Herbicide* 200, at heavy rates gave good results on brome grass but was not equal, on a pint to a pound basis, to *Experimental Herbicide No. 2* which gave promising results on brome. At low rates it had no effect on quack and gave doubtful results on alfalfa and sugar beets and caused injury to soy beans in wet weather. *Experimental Herbicide No.* 1 decreased the stand of sugar beets with some weed control, was very hard on soy beans, had no effect on quack at low rates and gave no control of weeds in flax but in an established stand of alfalfa gave good control of annual weeds and annual grasses with no injury to the alfalfa.

Ammonium thiocyanate at 50 and 100 lb./A was much less effective on quack grass than 25 and 50 lb. of TCA but was improved somewhat by supplementing with tillage. *Potassium thiocyanate* gave good control of quack with very high rates. *Chlorosol A* gave no injury to sugar beets and no weed control, was not absorbed into mesquite and on quack generally gave poor results.

A review of the results listed up to this point show some good, some promising and some no good at all. Several materials were worthless for one purpose but very promising for something else. Without knowing the nature of some of these materials it is difficult to visualize just why some of them were used as they were, and the motley array of results raises the question of how much preliminary work was done with some of them before they were sent out for trial by field research men. There remain five compounds to discuss — methyl bromide, MCP, PCP, 2,4,5-T and TCA and they will be discussed in that order.

Methyl bromide containing a small amount of chloropicrim has given clear cut results for the treatment of soil to kill perennial grasses, nut grass, weed seeds, nematodes and other organisms. It is applied under a gas proof cover and dissipates quickly from the soil when the cover is removed. This treatment is of special value for treatment of seed or plant beds, propogating beds, cold frames and greenhouse ground beds. It cannot be recommended indiscriminately for every crop because of some possible effects that are not well understood, but it is one of the new developments that has given consistently good results for many uses.

M.C.P. (2-methyl-4-chlorophenoxy-acetic acid) is a compound that has received considerable attention this year because of the indication that several crops may have a greater tolerance for it than for 2,4-D, but I have received abstracts on MCP from just one cooperator and he reports studies on oats, canning peas and several legumes. The general conclusions that I have drawn from these results are that; 1) oats are probably slightly more tolerant to MCP than to 2,4-D; 2) the yield of canning peas may be depressed by MCP salts; 3) legumes show a wide range of sensitivity to MCP and 2,4-D. Ladino clover tolerates both compounds and alfalfa is very sensitive to both. MCP seems to be definitely safer on alsike and red clovers, and white flowered sweet clover is rather sensitive to both, but with more MCP probably being a little safer. The evidence at hand surely is not conclusive but I believe that these results clearly indicate the desirability of a full exploration of the possibilities of this compound.

PCP (pentachlorophenol), as the phenol in oil and as the sodium salt, was, I am sure, used by many cooperators but again, I have received information from one source only. This report covered the work on soy beans and corn in one state which included extensive trials with PCP phenol in oil and the sodium salt. The sodium salt is indicated as "promising at times". The phenol in oil gave favorable results in normal weather but damaged beans in wet weather. The general conclusion reported is that it is "promising" but not equal to dinitro treatments on soy beans. PCP in oil at 8 and 12 lb/A gave good control of weeds in corn.

2,4,5-T (2,4,5-trichlorophenoxyacetic acid) is one of the outstanding newer materials but it is clearly indicated that it should not be considered as a general substitute for 2,4-D or even equal to 2,4-D for some uses. The general indications based on available information are as follows: 2,4,5-T is less active than 2,4-D on field bind weed and definitely inferior on buckbrush. It has shown definitely better results on poison ivy, horsenettle and ground cherry and with woody plants in general it is effective on some that have great tolerance for 2,4-D and is more effective than 2,4-D against other species. A partial list of plants on which 2,4,5-T is believed to be from somewhat to much more effective than 2,4-D in foliage treatments includes brambles, maple, oak, dogwood, hawthorne, persimmon, pawpaw, osage orange, sweet gum, wild apple, mesquite and possibly ash. The status of 2,4,5-T in comparison to 2,4-D is not clearly defined on in some of the so called sensitive species such as elder-

berry, sumac and willow. This may be a matter of adjustment of the rate of application. The advantage of 2,4,5-T over 2,4-D in dormant treatments on brush and stumps is even greater than its advantage in foliage treatments. Combinations of 2,4,5-T and 2,4-D have given good results in foliage sprays on brush but the excellent indications from 2,4,5-T alone makes it seem desirable to encourage extensive study of 2,4,5-T alone, especially in the form of the higher esters that are becoming available.

TCA in various forms was reported by more cooperators than any other new material. It was used in many ways and a concise summarization is impossible but some of the uses and general results will be indicated. Used on quack in black raspberries it caused serious injury to the berry plants which is in line with earlier use on several fruit and ornamental plants. Many crop plants are extremely sensitive to TCA and the soy bean is an outstading example as it will not tolerate even very small amounts. Low rates reduced the stand of onions, apparently lowered the yield of flax in one case and not in another. There is evidence of a degree of tolerance in certain crop plants such as the crucifers, sugar beets and flax. It is reported to have controlled weeds and grasses in crops in a few instances but apparently has no effect on wild oats at low to medium rates.

Prickly pear cactus apparently can be well controlled with TCA by spraying the entire plants at the rate of about 220 lb/A (2 oz. in 1 qt. to 25 sq. ft.) for the area covered. In another trial1 100 lb./A gave 90 per cent control of cactus. Brome grass sod was well controlled with sodium and ammonium salts but there is further evidence that esters of TCA are ineffective for grass control. Johnson and Bermuda grass can be controlled by proper timing. Johnson grass is evidently best treated when 12-18 in. high rather than with tillage or clipping which may mean that TCA is translocated in Johnson grass.

Quack grass has been treated more than any other plant and with many kinds of results. Most of the treatments were to growing quack during midsummer and there have been good results at low rates and poor results at high rates but the general indication is that 80 to 100 lb./A is needed to give reasonable expectancy of good results. There is evidence that spring applications are less effective than those made in midsummer. The statement of results in many instances was too vague to permit definite deductions and it sometimes was not possible to tell whether observations were based on top kill or on regrowth and most reports did not indicate if rhizomes were alive or dead.

Soil moisture at the time of and following treatment has been indicated as an important factor with not too much and not too little being desirable and one group of finely reported experiments indicates better results on sandy, sandy loam and loam soils than on clay loam and heavy clay soils with the indication that soil type may be as important as soil moisture. Another factor believed to be important is the carbohydrate reserves with a low reserve being a favorable condition.

The most outstanding and encouraging supplement to TCA for quack grass control is the use of tillage of some sort in conjunction with relatively low rates of application. The best combination certainly has not been determined but one series of experiments indicates three procedures that have at least doubled the degree of control obtained from TCA alone. They are: 1) plowing two weeks after TCA application, 2) shallow plowing followed immediately by spraying of upturned sod and 3) disking after TCA application. One test gave excellent control when applied to plowed and fitted land. The marked benefit of disking and plowing in conjunction with TCA is shown in the accompanying table which is adapted from the report of a well organized test on this point which included TCA alone, with disking and with plowing. The TCA was applied on April 20 and the plowing and disking were done on May 17.

Tillage	Reduction in stand (%) with		
	None	25 lb.	50 lb.
None	—	30	45
Disked	0	74	91
Plowed	10	85	91

I think you will agree after studying the results reported for TCA that it is a valuable and useful addition to the list of weed control materials. I believe, too, that it is obvious that intensive study is needed to enable us to clear up many of the factors that have a bearing on results. I will suggest that study of TCA-tillage combinations rates as the most important and most promising approach in TCA research, for the control of quack grass. Other important aspects are timing, soil moisture, soil type, carbohydrate reserves and movement and persistence in the soil as well as many other studies that many of you can think of.

Extension Weed Control in Iowa

E. P. Sylwester

Our weed control work at Iowa State College is divided into three phases, namely, resident teaching in weed control, research in weed control, and Extension education in weed control. During the past year, we held a total of 143 meetings throughout the state where weed control was discussed. These meetings embraced district meetings, county meetings, night schools, field days, meetings with special groups such as custom sprayer operators, weed commissioners, county boards of supervisors, chemical and equipment salesmen. These meetings attracted a total of 86,205 people. By far the largest meetings which we attended were joint weed and pest control clinics sponsored jointly by the State Department of Agriculture, the Des Moines Register and Tribune, and the Extension Service of Iowa State College. We held five of these meetings and the attendance averaged approximately 1800 at each meeting. At these meetings the various equipment and chemical companies all had exhibits.

The radio was used very extensively to supplement meetings of all types. A total of 40 radio talks was given concerning weed control. There were approximately 65 newspaper articles originating from our office in addition to those prepared by county extension di-

rectors. We issued one pamphlet, namely, "A Bird's-Eye View of Chemical Weed Control" of which 50,000 copies were printed and approximately 40,000 copies distributed. In addition, there were also six or seven mimeographed leaflets prepared on individual weeds. A series of Kodachrome slides was taken in hopes of preparing a complete set for this coming year. In our Extension program, we have tried to stress primarily, weed contol in crop land, in small grain, in meadows, pastures, along fencerows, and roadsides.

On the county level, 55 counties sponsored an active weed control program. The county extension directors conducted a total of 180 individual demonstrations. According to an estimate made by the county extension directors, there are approximately 24,500 farmers in Iowa who own their own sprayers. There are approximately 700 commercial sprayers operating in the state, an average of about 7 per county. According to their estimates, there were approximately 72,290 miles of fencerows sprayed in addition to roadsides. There were about, as last year, **1,000,000 acres** of corn and 500,000 acres of small grain, meadow, pasture, and flax sprayed in 1949.

In the coming year, we will sponsor in conjunction with our Entomology Department, a series of 38 district weed and corn borer clinics. These will start in January and continue until March. These are designed to bring the latest information on weeds and corn borer control to everyone of our counties but due to certain limitations, two or three counties will have to be handled at one meeting in order to save time. Iowa State College will sponsor an exhibit at these meetings and the exhibition of other chemicals and equipment will be up to the jurisdiction of the local committees in the communities sponsoring the clinics. In many instances, however, the meeting room will be too small to warrant extensive additional equipment displays. We will also have a single state-wide weed control conference in January which will contact all county boards of supervisors, weed commissioners, etc.

Next year we are going to put more emphasis on brush control by means of spraying and increase our program of roadside and fencerow spraying but temper it with extreme caution in regard to wild flowers and the elimination of wildlife cover where it does not interfere with traffic vision, snow removal, and power or telephone lines. We have had some very unfortunate cases of injury reported in Iowa due to carelessness in the use of weed killing chemicals. We are going to try to do everything in our power to prevent such damage in the future.

We look for continued interest in our program of weed control. Our experiment station has a very active program of weed research instituted and so we look for continued emphasis on weed control in the next few years. Our Extension work in weed control is geared very closely to that of our seed laboratory which stresses the pure seed approach to weed control. In the future as in the past, we will continue to put continued emphasis on cultural weed control, implementing and supplementing the good cultural practices of weed control by the use of chemicals. We believe that this is a rather fundamental procedure. While much still remains to be done in all phases of weed control, we definitely feel that our Extension program in weed control is geared to the farmer level and that slowly but surely it is gaining momentum and making the odious task of weed control more profitable, cheaper and less laborious for the farmer.

Weed Control Problems in Indiana

Oliver C. Lee

One might think that with all the recent progress made in discovering new methods of weed control that the problem is pretty well solved. This however is not entirely the case, and there are still plenty of problems to solve and plenty of weeds to kill. Most everyone will admit, to be sure, that the discovery of 2,4-D, 2,4,5-T, TCA and possibly other chemicals has been a great boost toward solving the weed problem. Not only are the present methds employed more effective but make the job easier.

The use of 2,4-D in corn to control weeds has made possible profitable growing of corn on land where weeds used to take the crop. Considerable acreage of corn in Indiana is grown on "river bottom" land where weeds are more than serious. The control of weeds is essential to growing a crop. The rotation on these lands is corn and soybeans. The only opportunity to fight weeds is when the fields are in corn. If the corn is kept clean, the results are reflected in the bean crop of the following year. Likewise, 2,4-D has helped to solve the morning glory, bindweed and Canada thistle problems of the uplands. Even though these weeds are not completely eradicated by spraying, they are subdued and the results should eventually mean fewer weeds.

The problem of the control of woody vegetation, along ditch banks, fence rows, highway power lines, and in land clearing has been encouraged, by the kills obtained by using 2,4,5-T and related mixtures. An enormous interest in this type of work has developed. It promises to be more effective than the old method of using the axe and far less expensive.

We in Indiana have two major grassy weeds to worry about, Johnson Grass and Quack Grass. Proper cultivation of course will eradicate them, but farmers are looking for an easier way out. Results with TCA have been promising. The material, however, is too expensive for large scale treatments. Work in progress now indicate that a combination of cultivation and treatments with TCA may be the answer. This work is still in the trial stages.

There are other problems that are far from solved. The control of weeds in truck crops and in pastures need attention. Such chemicals as stoddard solvents, sulphuric acid, dinitros, cynamate and others have a place in controlling weeds in truck crops. Pasture weed control is one that apparently can only be solved by a general pasture improvement program. A program is under way to encourag the renovation of pastures.

Encouraging the adoption of these weed control practices is the job of the extension service. Meetings are held, publicity written and demonstration areas established to show results. During the winter months a series of eight meetings were held for dealers selling herbicides and spray equipment. These

meetings were designed to correlate all information available on the subject. Some 900 dealers attended these meetings. Summer field days were held at which time results of weed control methods were shown. Implement dealers cooperated in these field meetings by supplying demonstrating sprayers and cultural machinery. Some 35,000 farmers attended.

There are still several problems to solve but progress in weed control methods has encouraged the farmer to do a better job of holding weeds in check. I believe we are on the right track.

Extension Weed Control and Organization in South Dakota

Leonard L. Schrader

A large number of farmers, ranchers, and other agricultural minded people from South Dakota and adjoining states are attending this three-day session to learn more about new and better methods of controlling weeds. They are concerned because of the large annual loss they take every year from reduced yields and a lower quality crop.

At one time this state of South Dakota did not have a single plant of the eight weeds now named as noxious. These weeds are: creeping jenny, leafy spurge, perennial peppergrass, perennial sow thistle, Russian Knapweed, Canada thistle, quack grass and horse nettle. They were all introduced mainly through seed brought in from foreign countries and from other states. Now they have invaded thousands of acres of valuable cropland and contaminated our seed and forage crops. This has called for a program of prevention and eradication.

The weed program in South Dakota is one of volunteer group action in controlling the eight noxious weeds that I have already named. Other weeds are also of concern, but the main program is one of ridding the land of the eight noxious weeds. People are taking to this program and wonderful results of group action are being obtained. Briefly, the program is first one of education followed by community or neighborhood and country organization, and as a last recourse, compulsion which applies to only those who refuse or fail to take care of their weeds. This is a long time program with the goal to obtain 100 per cent cooperation by every land owner operator, and organization in the state concerned with agricultural economy, to free the land from these hard-to-kill weeds.

The program is based on a community attack on weeds. The county agent conducts community educational meetings in all communities in his county every year. At these community meetings, the farmers discuss their weed problems, learn to recognize what weeds they have, plan a survey of the noxious weeds, discuss methods of controlling weeds and elect a community representative to represent their community in the county weed organization. Such communities then work together as a unit to reduce the infestations and to prevent the further spread of weeds and weed seeds. The different community representatives from thtroughout the county then meet together to elect a county weed board of three members who conduct the county weed program. Many county weed boards through appropriations made available by the county commissioners hire county weed supervisors to conduct the weed program in the county under the direction of the county weed board. The supervisor's job is not easy and requires much time and effort to assist farmers with chemicals, equipment and obtaining full cooperation from other county organizations as well as state and Federal organizations.

The county organizations receive assistance and guidance from the State Weed Board which is made up of the prominent leaders of agriculture in the state. They are: Secretary of the State Department of Agriculture, the President of the South Dakota Crop Improvement Association, the Chairman of the Association of Soil Conservation Districts, the Chairman of the State Horticultural Society, the Director of the South Dakota Extension Service, the head of the South Dakota State College Agronomy Department, the Commissioner of School and Public Lands, the President of the Association of County Commissioners, and one member of the State Highway Commission. This State Weed Board adopts regulations to the State weed law passed by the legislature in 1945 to determine the weed program of state. Three state weed supervisors have been appointed by the State Weed Board to follow the regulations and recommendations of the board. Enforement of the law, which applies only to those people who refuse to take care of their noxious weeds, is the duty of the Secretary of Agriculture of the State of South Dakota. This explains very briefly the weed program and organization in the state of South Dakota.

This weed program as outlined above was started in 1946 and counties differ in the progress they have made in getting organized into neighborhood or community units. Some of the counties are nearly completely organized and others are in the process of getting organized. For example, one of the counties containing 32 townships is organized into 120 different neighborhood units, each consisting of farmers that are fully acquainted with each other's problems of weed control. In this way the farmers can more easily plan a sound program of preventing weed seeds from being spread and contaminating the cropland.

In regard to weed control in the state, I presume that many of the problems are also similar to many of the surrounding states. The problems also vary considerably by areas of the state. South Dakota varies in crops from corn, oats, barley, wheat, soybeans, and flax in the eastern half of the state to a sorghum, wheat, and range grassland area in the western half of the state. The western half of the state also contains mountains and many acres of badlands. The soil varies from alkaline to neutral, to acid and sandy, to a heavy loam or gumbo in texture. Some of the counties contain a few acres of noxious weeds and other counties are badly infested, there being whole townships as one big patch. This is not a pleasant picture, and you will probably say that something should have been done years ago to prevent such things from happening. However, weed control is being practiced in every county in the state. The introduction of new chemicals and weed spraying equip-

ment has had an effect on the increased interest within the last few years.

It is estimated that there are approximately 7,000 ground weed sprayers on the farms and ranches in South Dakota. In addition to these sprayers 130 airplane pilots were registered in the state the past season of South Dakota and the remainder came in from other states. Generally, the results were reported as good, with less injury to crops than a year ago. I do not believe a large number of sprayers means too much, as the important job of an extension worker is to inform farmers about benefits, hazards and best means of applying weed chemicals at the proper growth stage of crops, the proper rates of application and putting the sprayers to work. Spraying is also only one phase of weed control and cultural practices are also very important.

The job of extension is one of education in supplying information on the latest and best means of weed control. You can easily understand then that the job of education will never end as new weed problems continually arise every year. The degree to which the people we work with are exposed to extension information through meetings, demonstrations, bulletins, news stories, radio talks, visual aids, and personal visits, largely determines their acceptance of recommended practices. As we look back at the results accomplished, how can we improve our techniques and methods of education in weed control to free the land of weeds that rob our soil of moisture and nutrients needed by our crops?

Perhaps the first problem of weed control is to help farmers and ranchers learn what the weeds look like and the seriousness of allowing them to invade the land. Colored pictures slides and growing samples presented at farmer's meetings and fairs help to acquaint farmers with these weeds. A number of weed calibration schools were held last spring to give the owners of sprayers assistance in learning how to operate their sprayers properly, in order to get the correct application on the weeds to be sprayed. At these calibation schools weeds were identified, the weed program explained, and demonstrations of weed control conducted. This proved to be one of the best means of assisting the farmers with their weed problems as the weeds were growing which made it much easier to talk about them.

Demonstrations are a very important method of showing the people what can be done by the use of recommended chemicals as well as those that are not recommended for use. Perhaps one of the best demonstrations we have all seen is where somebody has missed a strip through a field and the weeds are growing above the grain while the sprayed portion shows the weeds suppressed and the plants producing a bountiful crop. Pictures of such demonstrations are very valuable. A demonstration of the best means of weed control in showing how a thing is done, is one of the strongest methods of putting across a program. With farmers interested in getting rid of their weeds as they are now any help that can be furnished to them through demonstrations should eventually get everybody taking care of their weeds. Laws to force people to take care of their noxious weeds are then no longer necesesary.

What is the weed program planned for South Dakota in the future? We are already talking about taking some of our farm land out of production and diverting it to other crops such as grass, legumes, and crops that will not cause a surplus. As these acres are diverted, weeds definitely will try to invade the land. Then the thought arises as to whether or not it will pay the farmer to control the weeds on idle acres for the added return he will receive from the land sprayed. The cost of sprayers and chemicals still amounts to an expensive item to the farmer. The time may come when the cost of both will be even less than it is now and perhaps more farmers will use them in fighting their weeds, depending on the prices they will receive for their crops above the cost of spraying.

A weed manual containing the eight noxious weeds as well as 158 other weeds is at the present time in the process of being written. This is something that has been needed for a long time in South Dakota in the schools, in 4-H clubs and for the county agents and weed supervisors of the state. This manual will help people to learn to know the weeds they have on their farms. Weed identification is important and every year many farmers send weeds in to the office to be identified and they also bring them to weed meetings to learn what they are.

More counties will become more completely organized and more people will spray their weeds as they learn how to use weed killing chemicals and practice better methods of farm management.

In conclusion, I want to say that the farmers in South Dakota have accepted the weed challenge realizing that " it costs more to keep weeds than to control them". We realize that weeds are a community problem, and that the efforts of some individual farmers in the past have been very discouraging when working alone. Community or group action is necessary to obtain our goal in South Dakota in ridding our land of noxious weeds and in getting everybody working together as a team with this same view in mind. We need the help of our experiment stations in finding new and better methods in the application and use of new chemicals for weed control. Farmers are interested in everything they can learn here at Sioux Falls this week as well as the information we can give them in group meetings.

This is the picture of our weed program and organization in South Dakota. Many things still have to be done and counties are progressing rapidly in controlling weeds, organizing, and in learning how to free the land of noxious weeds.

North Dakota Weed Control Program

R. B. Widdifield

Chemical weed control in North Dakota during the 1949 season received more widespread interest and participation on the part of farmers of North Dakota as compared to 1948. This is illsustrated by an estimated two million nine hundred ninety thuosand acres being treated with 2,4-D in 1949 as compared to one million, five hundred seventy seven thousand acres in

1948 an increase of over 90 percent. These figures are the result of a state-wide survey this fall of county agent observations and estimates. While this survey cannot be considered as being accurate we consider it to be a reliable estimate.

About 95 percent of the creage treated with 2,4-D was selective control in growing crops with 5 percent being applied on summer fallow, grassland, roadsides, wasteland, etc. As to method of application approximately 80 percent was applied by ground sprayer, 7 percent by ground duster and 13 percent by airplane spraying. In cropland treated with 2,4-D 58 percent of the cropland treated was planted to wheat, followed in size of acreage by barley, flax, and oats respectively with smaller acreages of rye, corn, summer fallow and other crops.

Again in 1949 about one half of the counties reported that some injury had occurred from 2,4-D applications on growing crops. Most of the injury reported was slight and total acres injured would be well below one-half of one percent of the acres treated. While a good majority of injury cases seemed to be due to improper application there were again this year some cases that were unexplainable and where from all indications the job had been done as recommended.

In general, however, results obtained were very satisfactory. Due to the fact that in many areas of the state conditions were rather dry and the crops and weeds were not growing rapidly at the time of treating with 2,4-D a number of reports came in that control of some of the more resistant weeds such as wild buckwheat, canada thistle and sow thistle, was not as complete as in previous years.

A small amount of the dinitros are still being used in North Dakota with our summary indicating about five thousand acres mainly of peas and flax being treated this season. About two hundred thirty-eight thousand pounds of sodium chlorate, eighty two thousand pounds of atlacide and fifty two thousand pounds of borax were applied in the state this year in patch treatment of perennial weeds such as leafy spurge, field bindweed and quackgrass. About one thousand pounds of TCA were tried out by twenty nine counties on small demonstrations of quack grass control with good to fair results.

The educational program carried out in North Dakota in 1949 was somewhat less extensive than the previous years due to the fact that farmers generally are becoming more familiar with the use of selective weed chemicals. Our North Dakota Extension Bulletin was revised in December setting forth our recommendations for the use of chemical weed control for 1949 and about four thousand copies were distributed during the past year. State and district meetings were held on weed control and, although there were not any county demonstrations held this year, weed control was discussed at a number of county meetings throughout the state.

One new development in our educational program in North Dakota this year was worked out in cooperation with our State Civil Aernautics Board, the State Airplane Operators Association and the Extension Service in regard to improving the qualifications of operators in regard to aerial applications of selective weed control chemicals. This phase of our educational program has worked out very satisfactorily and based on the results this first season we believe has resulted in a lot of good with very little hardship on anyone. A plan was worked out with and agreed to by the Civil Aernautics Board the State Aerial Operators Association and the Extension Service wherein before a low flying permit would be issued by the Civil Aernautics Board to any airplane operator that copies of our Extension recommendations for both selective weed control with chemicals and recmmendations for the use of fungicide applications would be provided to operators and that before issuing a low flying permit all such operators would certify that they were familiar with our Extension recommendations. All operators also agreed that they would use a uniform reporting blank to be forwarded to the Civil Aernautics Board weekly including pertinent information on material applied, rate of application, crop conditions, etc.

This plan worked out very satsifactorily. It appears that there was considerably less serious injury to growing crops resulting from aerial applications this season and the reports filed on aerial operations has provided a very complete record of the 350,000 acres treated by airplane this season and provides the Civil Aernautics Board with more adequate information in regard to reports of injury to crops.

Another requirement agreed to in this procedure and carried out this season was that no low flying permit would be issued to any operator who might have an unsettled claim in regard to previous crop injury. This provision has proved to be a good protection to farmers without requiring the excessive cost esepecially to small operators of carrying liability insurance.

Another phase of chemical weed control that is being tried out more widely in the state this season is roadside spraying with 2,4-D. A number of countiese are trying out roadside spraying with a total of 2863 miles being treated in 1949 for the control of broadleafed weeds and miscellaneous trees and shrubs. A few counties are also trying out the spraying of irrigation ditches for weed control.

There has been rather wide-spread interest in North Dakota this year in the possibilities of TCA in patch treatment of quackgrass. Twenty nine counties carried out small demonstrations on quackgrass control with TCA this year using about 1,000 lbs. Results obtained with TCA on quackgrass this season have been rather spotted and varied considerably. In general, results obtained in 1949 were not as consistent or as good in quackgrass control as they were in 1948. Conditions were generally drier in 1949 as compared to 1948 which may have been an important factor. A number of the counties reported that considerable regrowth was occurring in the treated quackgrass patches this fall where TCA had been applied at about 100 lbs. of actual TCA per acre rate.

The interest and use of chemical weed control in North Dakota appears to be leveling off. It would appear at this time that the use of 2,4-D for the control of broadleafed weeds might average out at approximately application on 3 million to 4 million acres annually. In the first years when selective weed control chemicals such as 2,4-D have been available they are inclined to capture the imagination of farmers as

a sort of cure-all for the weed control problem. In this connection I would agree with Mr. Lee of Indiana when he says that we should not change our cropping systems or do not throw out old weed practices. North Dakota farmers are more and more coming around to the viewpoint that a sound long time weed contrtol program must include some of the older proven practices such as use of clean seed, a good crop rotation, use of grass and legumes in the rotation, clean summer fallow of row crops, proper seed bed preparation and other good tillage practices, use of early and late planted crops, smother crops, etc. and that chemical weed control is a very important new tool to be used along with these other practices.

Another viewpoint that is developing more and more in our state is that the final place of selective weed control chemicals may be to apply them at a certain place or on certain crops in the rotation to clean up weeds rather than in applying such chemicals on all of the crops or a large percentage of the crops each year.

There has been a considerable improvement in equipment for applying weed chemicals. The equipment for all methods of application available to farmers this past season was much improved over that even of one year ago. There has been a lot of improvement also in the chemicals themselves. The main improvement in this respect in chemicals used this past season was in getting away from precipitates forming in sprayer tanks, in using a lot of the hard waters available in North Dakota for weed spraying.

Motivations in Weed Control

Geo. M. Briggs

Human behavior is as mysterious as life itself. In thinking of appeals or reasons for our actions we wonder why children do certain things at times only to keep wondering as we grow older the reasoning of adults in doing things. Because of past experiences, or inborn inherited qualities, or acquired characteristics, there are those who want to work by themselves, who will become antagonized at suggestion of working with others, others may even have their pride injured if the dollar sign is the main approach to accepting a new practice and so considering all these differences in our makeup the idle gesture that "people are the queerest animals to deal with" maybe isn't so "idle" after all.

I question in our form of society if there is any *one* appeal to hasten acceptance of an improved practice. A good salesman would have to use nearly every known appeal to bring about desired acceptance and perhaps at that—repetition and persistency with it—so in extension—perhaps we have to be good psychologists because after all we are dealing with people that have the ability and power to make their own decisions.

The motivations or types of appeal cannot be listed according to their true values as what moves some to action yet will not be accepted by others. Among the many motivations the following ones are most common and regardless of them all, if the follower isn't in the mood to accept, no appeal is effective in developing this necessary want, or desire, which is so essential in bringing about acceptance of a new practice.

1. *Financial gain*—Some people have this alone as their measuring stick in acceptance of any new practice—and if the improved method cannot wear the cloak of the dollar sign it has poor acceptance. Some of the financial losses that we find in Wisconsin that really help influence people to acceptance of improved weed practices are the following: Bull thistle seed adhering to tobacco, weed seeds in legumes and grass seeds, weeds in cow pastures that taint milk, weeds in hay, weeds in grain fields—all of which lower the quality or reduce or hinder ease in harvesting.

2. *The ease in which the new practice may be adopted*—We seem to be living in the days of quick decisions. It may not be the expense or the total cash outlay that is involved that determines rejection or acceptance. It may be the time involved, or the accessability of equipment and materials or the simplified procedure. Again, maybe the deciding point will depend upon the ease with which the individual could carry on the program alone or in other cases with a truly cooperative minded soul—its acceptance will depend how he can cooperate with neighbors, which will lessen the cost and result in more joy in accomplishing it.

3. *Effectiveness of the new practice compared to the old*—What we have determined in our life helps determine one's path of progress. In considering new weed practices there must be a comparison of effectiveness of the new compared to the old as it relates to time required, expense involved and ease of bringing it about.

4. *One's resistance must be broken down*—All the persuasive oratory at our command, all the gracious gestures are to no avail unless thorough coverage of a community is being bought about. All people are interested in knowing what highway departments are doing, what plans and disposition is being made of neglected closeby property, what enforcement of regulations that have to do with weed seed reinfestation by thtreshers, combines, common haulers, feed dealers. These are all of first consideration.

The educational phases of informing people is not enough. It's the assurance to the people that legal phases of the program are not overlooked and that those in charge of the legal phases will follow through where necessary. The provision of the program that relates to preventing reinfestations from closeby neglected areas must be carried out.

5. *Pride in one's self family and his community*—As electric lights, shiny shoes, a smooth shave, new hat or shoes, clean and well pressed clothing, a sparkling auto, a straight furrow, and a straight fence line do stimulate self esteem, self respect, more or less dignity, so does weedless roadsides and clean fields. More and more parents realize the place that good example takes in directing paths to follow, not alone stimulate one's family but directs and stimulates others in the community.

6. *The appeal of human health*—Should adults responsible for carrying on weed control programs get just one good poison ivy infestation or a bad case of hay fever all barriers for carrying on a program against these weeds that contribute to such ailments

would be removed. One county paid out $1100 in hospitalization where road workers were involved in poison ivy problems—yet this was not as effective an appeal as it would have been had one of the supervisors been involved. Loss of time, medical expense, inconvenience, loss of income seem to be secondary in many cases.

7. *Hazards connected with the new methods*—Few practices are often subscribed to without fully knowing the after effects and all the implications. I don't know of any new practice for weed control that has fewer objections than the new weed control procedure when used according to the standard methods. Its effect on human health, on plant life, on equipment are all to be recognized with, but when understood, has fewer hazards than most farm practices. We could make long lists of common practices of farmers that all have hazards but knowing the problem farmers soon accept them and avoid injury when following safety measures. Examples: use of machinery, the use of electricity and the use of clothes cleaning fluids. In accepting any new practice we all make some blunders in the beginning and there has to be an understanding in terms we can understand and within our knowledge.

Perhaps the most recent misunderstanding of a mechanical defect and its remedy is illustrated by a housewife who filled her washing machine with hot water on a hot July day turned out the switch which resulted in blowing out the fuses, in questioning she remarked, "my husband said the mechanism was frozen so I tried to thaw it out."

8. *The appeal of example of leadership*—We all recognize the need of leadership: personally I think the followship is much more important. In advancing any new program there are those who like to be the first ones to take on, try it out or take it back—not necessarily that it will be the *example* for others to follow or that they may be the leader but this is leadership appeal that must not be overlooked.

9. *What neighbors are doing*—Believe it or not we are influenced by what our neighbors are doing. That is why mass action is brought about by mass appeal. When neighbors all give consideration to a united front it's surprising how easy it is for others to follow. The importance then is someone seeing that all are properly informed, and where not willing to cooperate, the legal provisions will be exercised and the importance of others knowing that the provisions will be enforced.

Movement of Noxious Weed Infested Materials

Bernhard C. Swenson

When man advanced through civilization from the period when food was obtained by the natural hunting-instinct method to the cultivating of crops and established an agricultural economy, his wanderings from place to place and from continent to contenent were accompanied by the movement of grains and seeds for cultivated crops. Thus it follows that the establishing of agriculture and man's contribution to the movement from place to place of weed infested materials was simultaneous. The subject of my discussion here today—The Movement of Noxious Weed Infested Materials—is inseparably linked with the general and broad subject of agriculture and food production.

The problem of producing adequate food, fiber and shelter, sufficient to meet the basic needs of human life, is undoubtedly the paramount concern of humanity when we consider the earth and its peoples as a unit. While the earth's land resources, suitable for crop production comprise only approximately seven per cent of its land surface, even this nominal amount is unevenly distributed and without correlation to population.

As an illustration of the lack of correlation of land resources to population, we find that in our country, the United States of America, we have approximately 417 million acres of cultivated or crop land; more than 3 acres per capita. By comparison, Great Britain has .26 acres of cultivated land per capita; Holland .30 acres; and the very densely populated continent of Asia, when considered as a unit, has only .40 acres per person.

The earth's area of cultivated or arable lands as of the present time, is incapable of producing sufficient foods to meet the needs of its people and the possibility of increasing the area of arable land is very limited. If the standards of living that obtain in the United States were universal, the earth's present production of food would support less than one-half of its present population, and conversely, if Asiatic standards were to become universal, the maximum population capable of being supported on present available food supplies would be approximately 3 billion people. When we consider that hundreds of thousands of the earth's people die annually for lack of food, fiber and shelter, it becomes apparent that the total world resources for the production of these basic commodities are of vital concern to all people irrespective of geographic boundaries of continents and nations. Factors that influence food production, and in the case of weeds compete with food and fiber plants, thus reducing the total production of food and fiber, are definitely of public interest and concern all people. The eminent English writer and poet, John Donne, has very aptly expressed what should be the sentiment of peoples everywhere as to the relationship between individuals and nations when he said, "No man is an island entire of itself, but each is a part of the main. . . Every man's death diminishes me for I am involved in mankind. And therefore never send to know for whom the bell tolls. It tolls for you."

Aside from humanitarian aspects, the economic factors involved in implementing control programs and our attempt to control or eradicate weeds in growing crops and on public lands are valid reasons for instituting such controls. Control processes increase annual yields and return heavily infested areas to production.

The cost of implementing weed control programs in our agricultural states and provinces can be illustrated by using as example one of our states where a total of 94 conferences were held during the calendar year 1949, at which more than 6,000 persons

were in attendance; and is further illustrated by the use in this one particular state of more than 16,000 power sprayers and dusters, and by the treatment of more than 2 million acres of growing crops. In addition to these expenditures on the part of the land operators, the public provides county supervision in all of the counties of this state plus supervision at the state level by 10 district supervisors, in addition to the administrative personnel of the Department of Agriculture, which agency implements the weed control laws of such state.

While the expense of control of weed infested areas is undoubtedly justified both economically and morally, the old adage of prevention being preferable to the treatment of the problem after it has occurred still holds. It would seem then, that *serious consideration by all of the agencies concerned should be given to the prevention of the spread of noxious weeds.* As has been previously indicated, one of the chief factors in the infestation of areas by noxious weeds is the movement of weed infested materials, in one form or another, by man. The agencies involved are of course several. A few years ago and just prior to World War II large quantities of government owned grains were being distributed for feed purposes. An analysis of the grain so distributed was made to determine the degree of weed infestations and in the state making such analysis, comprising 449 carloads, the results were as follows:

Average percentage of weed seeds in 449 cars	0.61%
Average number of kind of weeds per car	14.7
Total number of cars having quack grass	333
Average number of quack grass seeds per pound in each car	13.4
Total number of cars having field bindweed	45
Average number of field bindweed seeds per pound per car	1.8
Total number of cars having leafy spurge	1
Average number of leafy spurge seeds per pound per car	2
Total number of cars having perennial sow thistle	3
Average number of perennial sow thistle seeds per pound per car	1
Total number of cars having Canada thistle	21
Average number of Canada thistle seeds per pound per car	1.3

We are again approaching a period of government held grain supplies, and undoubtedly some of these government owned grains will again be offered to the public, eventually, for feed purposes. Thus the problem of weed infestation through the distribution of government owned grains is again with us. Federal agencies have given every indication that in the event of future distribution of government owned grains sold for feeding purposes, that such grains will be distributed in compliance with state laws regulating the distribution of feeds. Thus it becomes of paramount importance at this time, in order to effectively regulate the distribution of government owned grains and the normal distribution of whole grains, screenings, hay, straw and bedding for feeding purposes, which distribution is not now generally covered by the various laws regulating the distribution of feeding stuffs, that consideration be immediately given to the proposition of obtaining legislation on the subject. Preparation of a model feed control bill should be immediately undertaken by this conference, and the enactment of revised feed control laws should be considered by the various states and provinces.

The subject of weed control then becomes important and of public concern chiefly for the reason that it has a direct bearing upon and is a factor influencing our over-all supply of food and fiber. The elimination and eradication and control of weeds does not necessarily affect soil conservation. Plants have been developed or evolved by nature for the express purpose of aiding in the effective means that nature has, when left to her own resources, of protecting the soil by the prevention of erosion through the means of wind and water. In fact, these growing plants have a definite bearing upon the ultimate water level of the lands themselves. Having established the fact that maintaining, or the possibility of increasing the potential food producing capacity of the earth's lands, is of the most vital concern, and is in fact a life and death question for many of its people, the problem of weed control and elimination, to the degree that it affects food production, needs consideration both as it relates to control and elimination of weeds already on the land, *and to effect means of preventing further spread and infestation. From an economic and moral point of view the latter approach justifies far more consideration and attention than it has received by this conference, and by the various individual states and provinces comprising this conference.*

I wish again to emphasize the urgency of immediately providing for the appointment of a committee to consider the amending of existing feed laws and the enactment of such additional legislation as seems desirable and practical for the control and regulation of noxious weed infested materials.

The Problem of Cleaning Combines

L. W. Hurlbut

The external and internal cleanliness of a combine becomes of prime importance when an operator is preparing to harvest certified crops, preventing the spread of noxious weed seeds, or preparing the machine for storage. There is little need to restate the importance of these considerations from the standpoint of both producer and the combine operator. Yet, many operators and most designers have generally neglected the cleaning job as an important operational requirement in combining.

The design of the present day combine can be improved greatly by eliminating many needless and troublesome points of seed concentration on its exterior and interior parts. At those places where it becomes impractical to entirely eliminate the lodging of

seed, the designer must simplify the cleaning operation to the point where the operator can and will clean his combine before moving from one field to another and not just clean it when he moves from one state to another.

I realize that what has just been said has long been known and is not news to either the operator or the designer. In other words, both the operator and the designer has knowingly neglected this very important operational requirement. However, let this be a reminder to the combine designer that the burden of providing the solution of this problem rests on his shoulders. Better yet, he can consider this problem as an opportunity to make a very valuable improvement in his product.

In order to get a background for our study of this problem, we contacted six representatives from prominent companies manufacturing combines. Their replies to our questions clearly indicated a "general" recognition of the problems involved in cleaning or keeping a combine clean but there was a definite undertone of satisfaction with present designs—at least from the manufacturing standpoint. A few representatives mentioned such external features of construction as rounding tops and the elimination of a few external ledges but as a group, they agreed that there were many more problem points both internally and externally to be considered. A few of the more important parts mentioned were as follows:

External Points of Seed Accumulation

1. Ledges along the cutter bar and on the gathering points
2. Partially enclosed passages through the body of the separator
3. Canvas drapers
4. Grain bins, bin valves and auger bottoms
5. Valleys on top or alongside the separator section

Internal Points of Seed Accumulation

1. Concaves and concave circles
2. Boot covers for grain rakes
3. Main grain auger housing
4. Flat grain pans requiring a slat rake
5. Straw rack ledges
6. Ledges in the chaffer and sieve shoe
7. Tailings auger housing

While there were numerically more internal parts mentioned, it has been our observation that more weed seed and refuse is accumulated on the outside of the combine than is accumulated among the internal parts. Furthermore, it has been our observation that most of these points could be eliminated easily and economically by careful design planning.

Our presently incomplete study has been devoted almost entirely to cleaning problems related to the internal parts. The combine we selected is a popular small model owned and operated by our University Farm Department. It had been used last for combining sorghum.

We started by assigning one of our field crew, without knowledge of our study, to give the combine a thorough cleaning before delivering it to our machinery laboratory for class study. The external cleaning job involved a hosing with water after a detergent was applied to the grease-covered areas. The "so-called" clean machine was then given a more thorough cleaning by a senior student who disassembled certain parts, as recommended by the manufacturer, to facilitate the cleaning job. The student spent approximately four hours at this job. We cite this in detail to indicate just how impractical the present facilities and instructions are for cleaning combines. This experience confirmed our belief that various openings on existing combines have been strategically placed to permit unclogging operations rather than to facilitate cleaning.

Materials removed from the machine during the second and more complete cleaning were delivered to Dave Sander of our Agronomy Department who identified the following seeds: immature pig weed; immature kochia; alfalfa; kochia; pig weed; sorghum kernels; alfalfa pods; brome grass; yellow foxtail; sunflowers; wheat grass.

The location of the additional 6.3 pounds of material removed during the "second" cleaning was distributed as follows:

A. External
   1. Subject to direct spreading
      a. Behind the cutter bar and arround the main elevator canvas 7.8%

B. Internal
   1. Indirectly subject to spreading
      a. Straw-walker, grain pan and shoe (includes material from cylinder and concaves) 1.5%
      b. Return elevator and tailings auger 5.2%
   2. Subject to spreading through seed stock
      a. Main auger 31.6%
      b. Bottom of grain bin and bin emptying auger 53.9%

A high percentage of the material in the main auger and bin bottom was sorghum seed.

Considering only the internal parts of the machine from the standpoint of being a direct source of weed seed spreading when passing from one area to another, it becomes apparent that the parts involved are the threshing unit, the straw rack, frame ledges, grain pans, grain rakes and their boots, the cleaning shoe, and the return elevator housing.

To determine the relative importance of the aforementioned parts as carriers of weed seed, we feed only wheat grain into the combine and after a period of slow and fast operation of the machine found the remaining grain was distributed as follows: 5 per cent was in the threshing unit; 12% in the separating and cleaning unit; and 82% in the tailings auger. Stated in terms of kernels this means roughly 5500 kernels in the threshing, separating, and cleaning unit, and 25,000 in the tailings auger housing. From this quantity, we might expect a maximum of 300 kernels to move through the machine and on to the ground as the transient combine continues its harvesting operations. If the tailings auger were cleaned thoroughly then we could probably expect a maximum of 55 seeds to pass through the combine and out onto the ground.

In closing, I wish to re-emphasize that our combine cleaning study is incomplete and has been dis-

cussed on this occasion only from the standpoint of the combine as a direct spreader of weed seed as it moves from one field to another. We are aware of the fact that the problems of a certified seed producer encompass all the parts of the combine which may mix seed as well as spread it. The exacting requirements of certified seed production establish the real standards for good design in combines.

Summary of Discussion:

1. The external and internal cleanliness of a combine becomes of prime importance when an operator is preparing to harvest certfied crops, preventing the spread of weed seeds, or preparing the machine for storage.
2. The strict requirements of certified seed production establish the standards for designs which will eliminate the accumulations of seed inside or outside of the combine.
3. The burden of providing a practical solution to the combine cleaning problem rests upon the shoulders of the design engineer and the company management. Together, they must plan to eliminate many points which needlessly accumulate seed and to greatly simplify the cleaning operation at other points.
4. It appears that the tailings auger housing is one of the major internal sources for weed seed spread directly onto the ground by transient combines. This is probably true only where there are no grain rakes and complimentary boots required within the separator.
5. There is need for additional study on this problem and it is our plan to continue working on it.

Cooperation of Commercial Organizations in a Weed Control Program

A. E. Carlson

A weed control program is only successful to the extent that the desired objectives are understood and accepted by everyone concerned. It has always been evident that the successful weed control programs have been the ones where an attempt has been made to acquaint everyone with the problem. This involves a tremendous effort in developing a program and obtaining understanding and acceptance of this program.

In order to accomplish a reasonable percentage of this goal we resort to various means of promoting the methods of land use which will do most toward accomplishing weed control. In other words, we have something to sell. We obtain this from the channels of research. The information is obtained through study of each particular problem. These studies are conducted by members of Universities, Experiment stations and Industry. The cooperation between public fund research and industry research is excellent in exchange of information. The results of research are being evaluated and made available to us as recommendations. These recommendations of the most successful methods form the basis of attack to obtain weed control and eradication. It becomes our responsibility as members of regulatory services, extension services and industry to convey this information to the ultimate user. There are many opportunities which present themselves in this program where representatives of industry are aiding materially in promoting weed control. The term promoting is used here to describe various methods which prove the value of weed control. Promotional methods are employed in selling ideas, products or services. Many of the so-called campaigns for weed control whether originated by industry, extension services of institutions or public officials result in some gain as far as making people recognize the problem.

Advertising campaigns for use of products, equipment and services all have a common denominator of weed control. These messages carry the theme of benefit to the land user from weed control practices. Advertising is not limited to industry alone but is characterized in the information messages of publications, newspapers and bulletins issued by people interested in weed control.

Another method which is employed successfully is the media of a meeting. The weed control programs which I have had the pleasure of working with have held a regular series of area meetings each year. The purpose being informational and providing an opportunity to relay the latest information regarding weed control practices to the field. Commercial organizations sponsor meetings in the field, either in the form of dealer meetings or grower meetings. These povide an excellent opportunity to convey information regarding recommendations for weed control. The recommendations have to be specific and apply to the area where they are made. It is certainly the intention of everyone, member of regulatory staff, experiment station, or industry to use the most accurate information available as it applies to the problem of the area.

Frequently when a weed control problem is particularly difficult or when a new method of weed control shows spectacular results, a demonstration in the field can be very helpful to convince ourselves and our neighbors of the value of this practice. This is another place in a weed control program where commercial organizations welcome the opportunity to cooperate by assisting in the demonstration of a product, a piece of equipment, or a service.

We will all have to admit that in the past few years we have seen a tremendous interest in weed control which has been beyond that which could be predicted. I don't think we can say that this interest has been due to any one factor or any one weed control program. The interest in the newer herbicides which have made it practical and economical to control weeds in growing crops have certainly had some effect on public interest in weed control.

This interest has been further stimulated by more people in the field talking weed control, doing more research, and demonstrating the various methods whereby weed control can be considered a regular farming practice and can advantageously become a part of every land use operation.

In this discussion we have certainly not included all of the means of cooperation which commercial organizations can or do render in accomplishing

weed control. In fact in a broad interpretation of commercial organizations perhaps we have not included many services which are already rendered in this direction.

Speaking for myself without reference to any affiliation with commercial organizations I can only say that the cooperation and association with members of Regulatory staffs, Universities, Experiment Station personnel and Commercial Organizations has been very helpful and is very much appreciated.

I don't see anything which should alter this mutual benefit in furthering a weed control program and welcome suggestions whereby this cooperation can be improved.

Cooperation of Commercial Companies in Weed Control

W. L. Klatt

The value of organization and regulation is recognized by all interested in weed control. The importance of the regulatory and extension phases of a weed control program in acquainting all concerned with the weed problem and successful means and methods of control is also realized.

Commercial organizations know that the better the weed problem is understood, the greater the market for their equipment and products. Recommendations for the use of equipment and products for particular problems are most important. Success on the part of the user reflects in a successful weed program, whereas, failures in weed control tend to weaken the program and make administration and operation more difficult.

Mr. Carlson stated that recommendations for weed control have to be specific and apply to the area where they are made. This is most important and certainly shows the necessity of cooperation between regulatory, extension and commercial representatives in conveying such information to those interested in the distribution of chemicals and equipment and to those ultimately using them for weed control.

Cooperation between all groups is very good. No doubt there are still ways and means for improving cooperation. Such improvement will come about if attention is directed to those concerned. I believe suggestions will always be welcomed by representatives of commercial organizations, as well as by members of the regulatory and extension groups. Possibly if time permits, others present may have some additional remarks to add to the discussion.

Importance of Correlation of Research with the Control Program

Glenn Vlehmeyer

If the North Central Weed Control Conference is to operate with maximum effectiveness, it is mandatory that all divisions of that Conference cooperate in every possible manner. The conference has four major divisions, Research, Extension, Regulatory and Commercial. I would like to make the point that all of these are a part of an entity, rather than being distinct and separate units, that they must function as a single unit, if the problems of weed control are to be solved satisfactorily.

Each division has a job to do, it is true, but it is also true that it cannot do that job most effectively without the cooperation of the other three. For instance, the job of Research is to find out how and when to use the bewildering array of new herbicides that are being produced by the Commercial part of the team. Extension must carry these findings to those who will use the product. The Regulatory group must guard against the further spread of weed enemies, and be alert against the unscruplous person, who, for a little profit, would ignore the danger of distribution of infested materials. The Commercial group has the responsibility of producing the materials we need at a price we can afford. In other words, we are a team and the whole program is affected by how we operate as such.

If we in Research fail to properly evaluate new herbicides or if we ignore your need for immediate knowledge of research results, we fail in our obligations to you of the other Divisions and to the public. If you in Control and Extension do not inform the public of new developments and put such new knowledge into practice in the field, you also fail. There is no middle course, either we cooperate to the fullest degree or we fail to achieve the purpose for which the Conference was organized.

I do not want to give the impression that I think that all investigation must be conducted by the Research group, that all education is the work of Extension or that all regulation must be done by the Regulatory group. Such a policy could only lead to jealousies and hard feelings between Divisions.

As a Research man, I would say that my first obligation was to investigate, but that I should also stand ready to advise on methods of weed control or to report violations of regulations if the need should arise. Likewise, you in regulatory work should see and report any new developments or needs you may encounter in your field. We in Research, you in Control and you in Extension, are all understaffed and limited in finances; it is only by cooperation that we will be able to progress as we should.

As a member of the Research Committee I want you to know that we as a group and as individuals are willing to assist you in any special problems you may have, as far as our time and money will permit. Most of us have, and will again, talk to groups that you call together. This is as it should be and we are glad to do it. I hope you feel the same way about us.

We might take a look at a few of the problems that require the cooperative effort of the Regulatory and Research groups. In the case of movement of infested materials there is little that Research can do outside of reporting such violations as may come to our attention. I feel that we can and should assist in getting laws changed and made more uniform and that we must take part in resisting any attempt to tear down or weaken existing regulations.

In the field of noxious weed control there is room for, and need of, a great deal of cooperative effort. So far, we have just started investigation of the possibilities of chemical control of the major noxious weeds. Our present information on the subject, while extensive, has many gaps that must be filled. We must have more fundamental studies on physiological and environmental factors affecting plant response, if we are to use these new herbicides most advantageously.

To illustrate, I might cite a case observed near Hershey, Nebraska. A patch of bindweed that had apparently started as a single plant was treated with 2,4-D. The center of the patch was located on an irrigation lateral and the infestation extended several feet into the fields on each side of the irrigation ditch. The soil type was the same on both sides of the ditch. On one side of the ditch was an old stand of alfalfa while the field on the other side had been in corn and small grain for several years.

The treatments applied on both sides of the ditch were identical, yet the bindweed growing in the alfalfa was killed to a depth of two feet while that in the field that had grown cereals for several years showed no top kill and very little distortion of stems and leaves.

What is the reason for such response? Here we have two series of plants, presumably identical genetically and given identical treatments of herbicide, responding to that treatment in a manner that indicates high susceptability in one series and near immunity in the other. What causes such results and what are their significance in the problem of weed control?

Apparently we have been overlookings something that may be of vital importance in our control program. Perhaps many of the unfavorable results obtained in treating bindweed may stem from similar causes. Until we understand the reasons behind such plant response, we cannot hope to use the herbicides now available to best advantage.

Take a look at the results that have been obtained so far on leafy spurge, hoary cress, Canada thistle, Russian knapweed; weeds that are tougher to handle than bindweed. Even here we have occasional reports of good control. Why? Is it differences in varietal tolerance to the chemical used? Is it the stage of growth at which the plant was treated, or might it not concievably be, that the difference might be due to soil and nutritional factors that we have ignored in our experimentation? We must have the answers to such questions.

To find such answers will require teamwork; we will need the assistance of specialists in soils and plant nutrition, and of plant physiologists to determine the causes of such performances.

I believe that we can solve such problems if we want to badly enough. To do so will take a lot of hard and careful work by investigators in several specialized fields. It may require the development of new techniques and materials before the job is done; but I am egotistical enough about our organization to believe that it can be done.

Once we have found the basic reasons behind such plant response, Research must devise methods of applying that knowledge to field operation and Control and Extension must apply it to field practice.

If we are to function efficiently as a team, who is to call the signals? Who is the quarterback? In the evaluation of herbicides and in methods and time of application, this job falls upon the Reseach group. We must keep you of the other three divisions informed as to new discoveries and techniques that are applicable to your particular fields. I feel that you should be informed, not only of methods that have been proven effective by adequate testing, but that you should also know of new leads of promise, as they are uncovered.

It is the purpose of the Research Committee to bring this information to you by all means possible. The discussions and papers we are presenting during these three days are for that purpose. As most of you know, our Committee has been in session since Sunday evening; most of our group has been over the material to be presented in considerable detail. This material is now being presented for the benefit of those of you who were unable to attend the meetings that preceded the conference.

Some of the papers to be presented are reports of preliminary investigations and are probably not ready for field application. However if this new information is made available to you, it should serve to indicate possible future developments, and may, to a certain extent, assist you in planning future work.

In the field of education, we must substitute quarterbacks and let Extension call the signals. Certainly those in daily contact with the using public are in a better position to see the needs of information, then are we in Research or you in the specialized field of noxious weed control, and they should keep us informed as to new needs, as such needs develop.

When the problem is one of regulation, then you of the Regulatory group must take your turn at the quarterback spot, and inform the rest of us regarding problems peculiar to your own field.

I feel that your problem, or rather problems, are the most difficult of any faced by the Conference. Your division is comprised of representatives of eighteen separate states and provinces, each of these have different laws applying to weed control, and yours is the difficult task of coordinating these conflicting laws into something workable over the entire conference.

This will not be an easy task, or one that can ever be solved to the satisfaction of everyone concerned. Yet, it should be possible to work out some sort of an agreement regarding the movement of infested materials and of sanitary regulations for carriers and equipment, that are applicable to the entire conference.

The establishment of a uniform list of primary noxious weeds for the area included in the conference is badly needed, yet, each state and province has laws that differ in varying degree. Such a list of noxious weeds should be uniform, not only within the Conference, but should also be in agreement with lists of the other Conferences in Canada and the United States.

To achieve such uniformity will be a difficult task. You will be affected by politics and pressure groups that will insist on liberal laws to permit movement

of infested material across State and Provincial boundries. Unfortunately, these political and pressure groups may not be concerned with the problem of weed dispersal, but rather with the immediate profit to be made by distribution and sale of infested materials. Where the profit motive is involved, the resistance to corrective measures will be greatest.

Perhaps before the desired ends can be achieved, it may become necessary that we establish a pressure group of our own, to advise with law making bodies on weed control legislation. If necessary, I believe this can be done.

You in Regulation may, in actual field application of our recommendations, find weaknesses in our research results that must be corrected. I feel that you should inform us of such faults so that corrective measures may be taken. It seems obvious to me that such weaknesses are to be expected. The area covered by the Conference is so vast, soil and climatic conditions so different, that results of a treatment are bound to vary from place to place. The problems are so many, and Research workers so few that it has been impossible to work out the answers of each problem for all environmental conditions.

In many cases, it has been necessary to make our recommendations on the basis of inadequate data; where recommendations are based upon limited data it is not to be expected that they will apply to all cases.

Where such exceptions occur, you should report them and ask that additional investigation to clarify the problem be undertaken.

Again I ask you to remember that we are a team, not separate organizations. Our problems are common problems, our aims common aims. Let us forget petty jealousies and differences of opinion and work as a team. If we will do this we can answer the problems of weed control.

Weed Control on Highways

Dudley B. Chittenden

An effective weed control program for local, county and state highways is based upon two fundamentals common to all good weed control programs. These are (1) a comprehensive weed law that adequately covers the entire problem and (2) effective enforcement of all the provisions of the law.

There are three methods of controlling weeds on highway rights-of-way. The first and most important from an economic and aesthetic point is the use of a vegetative cover of desirable grasses and legumes. The second method is a properly timed mowing program aimed at the prevention of weed seed production. Chemicals, the third method, should be used when the other methods prove inadequate.

The establishment of a vegetative cover is most easily accomplished through seeding the desired species of grasses and legumes, but can also be accomplished by sodding or sprigging methods. These latter two methods are, however, quite expensive and are economically justified only where erosion cannot be controlled by other means. Seeding costs in Iowa on 1949 construction averaged $26.42 per acre, including the cost of the seed. Sodding costs averaged $4.98 per 100 square feet or $2,170.00 per acre. No sprigging is done on Iowa highways.

There are several grasses that are adapted to use on highways over most of the area included in this conference. These include Bromegrass, both northern and southern types, Crested and Western Wheatgrass, Kentucky Bluegrass and Redtop. Legumes used include Alfalfa, Red Clover and Alsike Clover with Korean Lespedeza used in the southern portion of the area. There are other grasses and legumes that are used to a limited extent but these are the principal species in use.

Bromegrass is used more than any other grass due to its wide adaptability and its large vigorous growth which can effectively compete with weeds. The only fault with Brome is that it is slow in becoming established but early fall seeding in Iowa has resulted in good stands the following year.

The Wheatgrasses are adapted to those areas having low rainfall and they are big and vigorous enough to crowd out many of the weeds.

Bluegrass and Redtop both form an acceptable cover in those areas of sufficient rainfall and are used largely because of the ease with which a stand can be established.

Alfalfa works well in mixture with Brome in those areas where soil and climatic conditions are favorable. The Clovers seem to become established more readily on heavier soils and will tolerate more moisture than will Alfalfa. No legume will remain in the stand indefinitely but Alfalfa generally outlasts the Clovers in Iowa. Rarely does Alfalfa last much over 10 years with the Red and Alsike Clovers dropping out in 3 to 7 years, depending upon local conditions.

Seed mixtures in use on highways over the United States vary to the greatest of extremes. A recent study of 40 highway seed mixtures used in 10 states, revealed that they contained from 1 to 7 species of grasses and legumes, and were sown at rates from 9 to 261 pounds per acre and ranged in density from 0.53 seeds per square inch up to 129.1.

At the present time Iowa uses the following grass-legume mixture.

Bromegrass	15 pounds per acre
Alfalfa	5 pounds per acre
Red Clover	3 pounds per acre
Alsike Clover	2 pounds per acre

This mixture has a theoretical density of 0.85 seeds per square inch. In addition a nurse crop of 1 bushel of Rye per acre or 1½ bushels of Oats per acre is used.

Soil admendments such as lime and fertilizer are, at times desirable in the establishment of a good vegetative cover but have been used to only a limited extent in Iowa.

One of the most effective aids in establishing a vegetative cover is the use of mulch. Hay or straw spread uniformly over slopes at the rate of 3 to 5 tons per acre will help prevent seed from blowing or washing away, will prevent puddling of the surface and consequently increase the infiltration of rainfall and will offer some protection from hot sun and winds. If only one item of a seeding-mulching- sodding program were to be singled out as the most im-

portant, mulching would be the one. If the soil is retained in place some sort of vegetation will eventually become established. Mulching costs in Iowa for 1949 averaged $90.32 per acre for the material and spreading.

Perhaps the oldest means of controlling weeds on highway rights-of-way is by mowing. This method is very effective if properly timed to prevent the production of weed seed. One mowing is not sufficient to control all of the weeds now found on the roadside and two or more mowings should be properly timed to catch the plants just before blooming. While one or more mowings a year are of considerable benefit from the standpoint of appearance and increased vigor to the grass, even though improperly timed, much more benefit can be obtained by studying the problem and mowing accordingly.

Nearly all mowing is now done with sickle-bar mowers but the day is not far off when highway engineers will be designing and building highways in such a manner that reel type mowers similar to those now used on golf courses will be used for roadside mowing. The effeciency of these mowers is roughly six times that of the sickle-bar mower and even though three mowings would be required to one of present standards, the cost would be approximately halved.

Even though chemicals are achieving wider use each year, it does not appear probable that spraying will ever replace mowing completely on the roadside. Mowing can increase the vigor of grass and present a neater and cleaner right-of-way than will be possible through the use of chemicals alone.

With the advent of 2,4-D weed control took on a glamour never before known. At first it appeared that weeds would be forever banished from the earth. This point of view has been tempered considerably, however, and it should be remembered that chemicals are the last resort when other practices are not sufficient to do the job. In the past few years chemicals have been developed that will kill or effectively control nearly all types and classes of vegetation. Due to this rapid advancement in chemical weed control methods it is now possible to select one or more chemicals for each problem.

In most highway departments weed spraying operations are carried on by the regular maintenance forces. Not more than one or two rates of application should be employed and these should be very general in character. It appears to be a better practice to apply chemicals at rates sufficient to control all species involved rather than attempt to sort out the susceptable species from those that are more resistant. In most highway departments it is manpower that is lacking and follow-up work is often entirely neglected.

Rates of application cannot be specified accurately in a large percentage of the cases. When working in heavy weed or brush growth the rate of application must, of necessity, depend upon the judgment and skill of the operator. For the average condition an application of 1 pound of 2,4-D acid per acre is sufficient for effective control if applied while the plants are in the active growth stage. If the plants are resistant due to species or stage of development the rate can be increased to 1½ pounds of 2,4-D acid per acre. A mixture of 50 per cent 2,4-D and 50 per cent 2,4,5-T applied at the rate of 1 pound of acid per acre has proved effective on resistant species.

There are several other chemicals that have a place in the highway weed control program. Among these are ammonium sulfamate or "Ammate" which gives a quick top kill as does "Atlacide." Ammate should be applied at the rate of 870 pounds in 450 gallons of water per acre for average conditions. Atlacide at the rate of 400 pounds in 300 gallons of water per acre is sufficient for average conditions.

Borax has shown promise of giving good control on deep-rooted perennial weeds. Applied at the rate of 10 pounds per 100 square feet or 2 tons per acre, Borascu has given good control on Leafy Spurge, Canada Thistle and Bindweed in Iowa. This chemical sterilizes the soil to some extent but tests conducted this past year indicate that the area may be reseeded in March or early April following a fall application of Borascu at the above rate. Alfalfa showed a good response in these trials while Red and Alsike Clover showed only a slight effect from the residual boron presumably present. Bromebrass gave spotty results but where sown in mixture with legumes the response was quite satisfactory.

Equipment for the application of chemicals to roadsides varies about as much as it does for anything else. It appears that some study should be given to the problems involved in roadside spraying and develop equipment better suited to this particular phase of weed control.

The use of chemicals in weed control work accomplishes a single purpose and that is the control or eradication of existing weeds. To accomplish the most desirable final result a policy of reseeding should be used in conjunction with chemical control. In many instances a small amount of time and money spent for reseeding can correct a bad weed condition by substituting desirable grasses and legumes for the undesirable weeds. Smother crops are accepted as a good method of weed control and a good roadside vegetative cover is one of the best smother crops.

Briefly, then, a good roadside weed control program should consist of three main parts.

1. Good grass and legume cover.
2. Properly timed mowing.
3. Chemicals to control the persistant weeds, followed by reseeding of desirable grasses and legumes.

Weed Control on Highways

D. K. Pryor

As a County Weed and Seed Supervisor I think it is essential that a good Weed and Brush control program be carried on on roadsides, if we are to expect the full cooperation of the people living adjacent to our Highways. This can best be brought about by a combination of chemicals and mowing or cutting in some way. The starting place for this should be on county or/and state maintained highways.

One very satisfactory method is a chemical application where necessary during the season, and with one mowing operation later in the fall of the entire mileage of roads.

When chemicals are used it is important that the

crops adjacent to the road be taken into consideration, also the kind of weeds or brush, legume seeding, kind and type of chemical, time of application, weather conditions, equipment, pressure and coverage.

If sensitive crops are growing adjacent to the roadside it would be a good policy to talk this over with the farmer and get his permission to spray. This would in certain instances absolve the sprayer operator from any damage that may occur.

We must keep in mind that all chemicals put on in the form of a wet spray will drift. In the case of 2,4-D it is well to remember that non volatile ester is more practical to use, especially where there is danger of crop damage. Otherwise other types of esters or a combination of 2,4-D and 2,4,5-T are recommended.

Sprayer equipment, first a good pump is essential, one that has ample gallonage and will develop up to 400 pounds of pressure; a boom that will cover most of the roadside————this generally takes about 23 feet, a good spray gun and a jet nozzle as the standard equipment.

In brush spraying it is important that good coverage be attained and this can best be done with a nozzle that has a capacity of not less than 20 gallons per acre. The more gallonage the better the coverage. Reports in Minnesota indicate that too early spraying of brush may lend itself to poor results. The month of July seems best in the southern half of Minnesota and a little later in the northern half.

We should also take into consideration the temperature and if possible stay above sixty degrees. Indications are that ample moisture in the soil is a factor which adds to better results in the use of these chemicals.

We must not forget that we have our older chemicals such as Sodium Chlorate and Borax and some new ones that work on the same order. These chemicals still have a definite place in weed eradication, and should be used on small patches of hard-to-kill perennial weeds.

There is one thing that will do more for weed control on highways than all of the rest put together and that is back sloping where ever possible and seeding it down in a good hay crop, in order that this might be mowed, at least two or three times per season.

I have a few figures on what has been done in Minnesota in regard to weed control on highways this year.

Number of miles of State Trunk Highways sprayed with chemicals in Minnesota 3,167

Number of miles of County Aid Roads sprayed with chemicals in Minnesota 13,130

Number of miles of Township roads sprayed with chemicals in Minnesota 6,099

It is important to remember that in cleaning up roadsides that we do not permit these areas to become reinfested by allowing infested materials to be hauled over these roads.

Controlling Inter-State Movement of Combines

L. V. Ausman

Mr. Chairman and gentlemen, I am very glad to be here and participate in this North Central Weed Control meeting. After having sat through this meeting from 1:30 to 5:30 this afternoon, I am well aware of the fact that the head can not absorb more than the seat can stand, so I will try and make my part on this program quite brief.

The work of regulating the inter-state movement of combines and harvesting machinery is so new that we have made no definite conclusions and we do not feel that any can be drawn for sometime. We are still pioneering.

Our first experience in regulating combines and trucks coming into the State was in 1947. That year 5420 combines and trucks were inspected. This number was increased in 1948 to 7370. Due to the lighter harvest in 1949 we only inspected 3170 combines and 3379 trucks or a total of 6549. The total machines inspected in the three years of the program was 10,566 combines, 8,733 trucks or a grand total of 19,389 vehicles.

I believe that you will be interested in some of the difficulties that we have encountered and how we have solved them. You are probably interested in some of the problems that we met that have not been satisfactorily solved. Maybe you can help up solve them.

We have six ports of entry in South Dakota scattered along our southern border. They are located at Yankton where Highway No. 81 crosses the Missouri river, at Fairfax, Colome, Mission, Martin and Oelrichs, which is near the Wyoming border. They are located on highways leading into South Dakota from Nebraska since the harvest season moves from south to north. One man is in charge of each inspection station. In addition two members of the Plant Industry Division are assigned as inspectors at large and oversee the general inspection at the ports of entry.

These stations are mostly located near filling stations and near the edge of town. One of the good features of this set up was that the combine operators could get gas and oil and make minor repairs while stopping for cleaning of their machines. In one case this was not advisable since the nearest town was eight miles from the State line and the people in that community thought the inspection station should be at the state line rather than in their town.. This made it somewhat inconvenient for the operators, but it seemed most practical in order to better prevent the spread of noxious weed seeds into that area.

Most of the combines and trucks have been cleaned by the use of brooms and whisk brooms. This process usually takes and one and one-half hours per machine for two men. This method is much too slow. Many operators have stated that they would gladly pay $3.00 or more per machine if this work could be done in 15 to 30 minutes. This is one of the problems that we have not solved as yet. We are hoping that some efficient type of blower, operated either by electrical

or truck power, can be perfected so that the cleaning time can be materially reduced.

The size of the inspection yards vary from approximately a city block to three acres. It must be large enough so that large numbers of combines and trucks can move into and out of it at all times so that there will not be any interference with the movement of other vehicles or interruption of cleaning operations.

The season runs for 30 days and the inspectors are paid from $10 to $12 per day, depending on number of vehicles processed and training and ability of operator. By law they are vested with police power.

Traffic could be a problem but to date it has not been. An effort is made to locate the stations a suitable distance off the main highways. Large signs directing machines are posted not less than 300 yards from each station. Red flags are placed on the roads in all directions from the stations. With these precautions we have had no traffic accident and no serious problem has arisen.

After cleaning, each machine is tagged with a green tag, which contains the following: (1) a statement that the operator is cooperating with the South Dakota Weed Control Program, (2) a copy of the regulations governing the control of noxious weeds and, (3) instructions for cleaning machines and equipment. The green tag is attached by wire in a conspicuous place on the combine or truck. These green tags are made of heavy cardboard which is water repellant and must remain on the vehicle while operating in South Dakota.

Daily records are kept of the work at each station. This record includes the type of vehicle, whether combine or truck, the name and address of the operator and the tag number.

One of the problems that has not been solved is cleaning the stations of the accumulated material, such as straw, weed seeds, dust, etc. It has been partially solved by the use of incinerators and by burying the refuse in a deep hole. Lack of funds for such expenses have been a handicap. Plans are being made to make provisions in future appropriations for funds to secure such equipment as incinerators and brooms, to rent power equipment for use as blowers to clean equipment, to pay rent of land used for inspection stations and to pay for electrical current. The solution of these problems would be a big step forward in the efficiency of the campaign.

This program of compelling the combines that come into the state for custom harvesting to be free of weed seeds is very popular. The interest is so great that this year when the harvest was more than a week earlier than normal the Governor received letters regarding a few early combines that were moving into the state before we had our stations set up. By the time the Governor had these reports and contacted our office the stations were in operation, but it was definite proof of the interest in the program.

One fact that is very noticeable is that each year the combines coming into the state are much cleaner than those coming in the previous year. With one exception, in three years, the operators were very anxious to cooperate in having their equipment free from noxious weed seeds. This is true at our ports of entry. We do not have a sufficient force to do much follow up work. In the few check-ups that the inspectors at large have made in the state-wide inspections, the results have been very satisfactory.

South Dakota farmers and ranchers moving their own machines, combines and farm equipment used in threshing operations within their various communities, should also comply with these regulations. The cooperation of inter-state combine operators would be in vain if we did not receive full cooperation from South Dakota farmers and ranchers.

Actually everyone connected with this campaign is very happy with the results so far. We know that there are many improvements necessary, but with the wholehearted cooperation that we are receiving from all parties involved we believe that our combine inspection work will be a big factor in South Dakota's weed control program.

The National Picture in Aerial Spraying for Weed Control in 1949

L. M. Stahler

A number of very obvious factors have contributed to the large scale usage of 2,4-D for the control of weeds in this area and likewise to the phenomenal development of aerial application of these herbicides. This area, is roughly bounded by Texas on the south and the western Canadian Provinces on the north, has an agricultural economy based on production of cereal grains——wheat, corn, oats and barley. These crops with their high tolerance of 2,4-D, combined with the relatively susceptible annual weeds that infest them, present an almost perfect situation for the employment of a selective herbicide such as 2,4-D. Further, the absence of localization of 2,4-D sensitive crops in this area devoted to the production of cereals, has favored the use of planes in application of 2,4-D as a fast economic and large scale operation.

Realizing that most of you follow the aerial spraying season from Texas to Canada, I have in preparing this talk gathered information and data from agricultural research and extension leaders in each of the states and provinces in the area. While I do not have complete data from each of the states contacted and while the answers to my questionnaire were in many cases acknowledged as being "statistical guesswork", the data resulting from these questionnaires does, I believe, give a quite clear and balanced picture of the growth and development of use of herbicides in weed control and also the part that aerial application of herbicides has in this development. I want to here publicly express my appreciation of the assistance that response to my questionnaires has given me in gathering these data.

In the first place a survey shows that in 1949 South Dakota had a greater total acreage treated with 2,4-D than any other state. Their survey shows three million acres treated; whereas only one million acres were treated in 1948. This is by far the greatest increase in acreage treated with 2,4-D reported by any state in the survey. North Dakota ranks second in actual area treated with 2,990,000 acres; Minnesota third with 1,680,000 acres; Montana fourth with

1,600,000 acres. In the case of Montana this represents a decrease of 200,000 acres, as their reports show 1,800,000 acres treated in 1948. Nebraska and Kansas each report approximately 1,200,000 acres in 1949. Oklahoma reports 600,000 acres treated of which only 250,000 acres were in cultivated crop.

The total area treated for weed control in these states is in excess of tweive million acres. For purposes of comparison the six states of Missouri, Wisconsin, Michigan, Illinois, Ohio and Indiana estimate a combined total area of slightly under two million acres treated with 2,4-D in 1949.

The three western Provinces of Canada———— Alberta, Saskatchewan and Manitoba report 8,200,000 acres treated for weed control in 1949, an increase of approximately three million acres over 1948.

As aerial spray operators you are naturally interested in the entire picture of the growth and development of 2,4-D, but certainly more specifically interested in the part that aerial spraying plays in this development. As a result of the survey made in the western Mississippi Valley States, data show that of the twelve million acres treated in 1949 approximately 2½ million were sprayed by plane, or 20.8 per cent of the total. In total acres sprayed by plane Kansas leads with 800,000 acres, while Nebraska and South Dakota report 400,000 acres each sprayed by plane. North Dakota and Oklahoma are tied for third position of importance with 350,000 acres each sprayed by plane in 1949. Montana reports 150,000 acres sprayed by plane, while Minnesota data indicates only 80,000 acres treated by plane and 1,600,000 acres treated by ground driven equipment. Surprisingly the western Canadian Provinces report only 30,000 acres sprayed by plane with 8,170,000 treated with ground driven sprayers and dusters.

Now let us consider the entire picture of herbicide application in this great area in which you are primarily interested as plane operators. In the first place, the total use of 2,4-D in 1949 is below the figures which I, and many others, estimated a year ago. Several factors contributed to this error in our estimates. We had a very unreasonable growing season over the entire area. In the southern winter wheat area an extremely dry fall and early winter season was followed by a prolonged period of light to moderate rainfall which extended well through the normal herbicide spraying season. The dry fall and winter resulted in poor growth and stands of wheat which while favoring development of annual weeds in many cases made the farmer so uncertain of a profitable harvest that he either fallowed his fields or was unwilling to invest the cost of weed control in an uncertain crop. When precipitation did come in this area it lasted too long and wheat developed beyond the optimum stage for treatment with herbicides before weather conditions would permit of any large scale aerial spray operations. Further factors that affected the aerial spray picture in the winter wheat area were the slow development of weeds and the uncertainty of the dollar value level of the crop. Spraying of range land for control of sand sage and other woody perennials was likewise limited by the poor weather conditions existing during the optimum period of herbicide application.

From mid-Nebraska and north through the Canadian Provinces — in the spring grain area, spring drought with uncertainty of crop production was likewise followed by a long period of rainy weather and high winds that markedly limited the productive spray period. A most important consideration here also is the tremendous increase in use of ground driven sprayers and dusters for application of herbicides.

The below normal moisture conditions in the corn growing areas were conducive to efficient cultivation operations and annual weeds were not a serious problem in corn as they have been in previous seasons with above normal spring precipitation.

Due to the above factors I found in general that the well organized aerial spray operator had more acreage contracted at the beginning of the season than he was able to service or handle in the short operational period that pervailed. In fact, in considering all of the adverse factors just mentioned, it is rather surprising that the total acreage plane sprayed in this area in 1949 is as great as the survey indicates. On the basis of the fact that aerial spraying in 1949 was greatly hampered by weather conditions — precipitation and high wind velocity, I would forecst an even greater use of ground driven sprayers in 1950 and secceeding years. Data of my survey indicates that local state observers consistantly estimate a considerable increase in number of ground sprayers in 1950. Therefore, unless the total acerage treated with herbicides in 1950 expands greatly, I would further forecast a smaller acreage, and a smaller proportion of the total, being treated by plane in 1050. If the total acreage treated with herbicides in 1950 in this area under consideration levels off at approximately 12 million acres and we have ten to 20 per cent more ground driven sprayers and dusters in the area next year, the acreage available for plane spraying is bound to drop in proportion.

Data of my survey indicate that approximately 600 planes operated in the area under discussion. Exact figures on the number of planes are very difficult to establisch as we find that almost universally planes licensed in one state, operate in one or more of the other states under consideration. On the basis of the figures that we have, however, simple arithmetic allots approximately 4,200 acres to each aerial spray plane operating in the area in 1949. I well realize that many operators had planes that treated four to five times this area in the past season. I also know several individual operators who last year treated less than 1,000 acres. However, I am interested in this consideration because of the fact that several large operators have informed me that their records indicate that five to six thousand acres per plane is a minimum efficient unit area per season. On the basis of the figures summarized this season and in the light of the estimated increase in number of ground operated sprayers and dusters for 1950 it becomes quite apparent that we either have too many spray plane operators, or that we will of a necessity be forced to increase the total use of 2,4-D in order to assure an economic operating field for the present number of spray planes in this area.

The future picture of aerial spraying is not, however, as dark as you may think I am painting it. While I am convinced that aerial spraying for the

control of weeds in grain has about reached it's maximum development in this area and that seasonal weather and growth conditions will of a certainty in some years result in a much lower available total acreage for plane spraying than we had in 1949, I want to emphasize that you have yet barely touched your most unique field of spray operation. This is the application of herbicides for control of herbacious and woody weed growth on pastures and range land. Scattered throughout and uniformly over your field of operation there are millions of acres of rough pasture land not adapted to ground spray application of herbicides that could be economically improved by plane spray application of 2,4-D or 2,4,5-T. I am not thinking of the large acreage range areas now but of the average farm pasture and meadow. We have long ago shown that some of our most common northern pasture weed species such as ragweed, fleabane, marshelder, cocklebur and gumweed can be satisfactorily controlled with applications of 2,4-D made at the proper time. Yet my observations indicate that there has been practically no change in the management of pastures infested with these weeds and the average northern pasture is almost completely taken over by one or more of these species by mid July each season. A little demonstrational or missionary work on the part of local spray plane operators could easily establish the efficiency of spray plane application of 2,4-D for the control of these weeds and build up a local spray plane service that in the aggregate would vastly expand the aerial spray acreage for the area.

Buckbrush, hazelbrush, prickly ash and other woody pasture weeds commonly found in uncultivated grazing areas in the northern one-half of this area, likewise, have been demonstrated to be efficiently controlled with proper application of 2,4-D or 2,4,5-T. The variation in species infesting pastures locally and the economics of control are factors that make aerial spraying of these species a local problem and business and one that can best be worked out and developed by the initiative of the local spray plane operator.

For the individual organization that operates spray planes over the entire area on a seasonal schedule the great hope for expansion lies in the south and southwest, in the control of woody growth on the extensive range land. As an example of what these developments can mean to aerial spraying, let us consider what has happened in the Panhandle region of Kansas, Oklahoma and Texas. Sparked by the research and investigations of the Southern Great Plains Field Station at Woodward, Oklahoma, 100,000 acres of sand sagebrush was treated in 1948; 330,000 in 1949. Application of herbicides for the control of sandsage is ideally suited to plane sprayers, as indicated by the fact that of the 1/3 million acres treated this year only 25,000 acres were treated with ground driven equipment. I should hasten to add that the sandsage area has only been touched as data indicate that Texas has 6,400,000 acres infested with this species, Oklahoma 600,000. The investigations at the Southern Great Plains Field Station not only showed that sandsage could be controlled on range land with 2,4-D applied by plane but also showed this practice to be highly economical from the ranchers viewpoint—data in 1948 indicating an increase in beef production of 40 pounds per acre where sandsage was controlled. When we have similar data to illustrate the efficiency and economy of control of other brush species the field of aerial spray application of herbicides will be tremendously increased.

As an example, Texas has approximately 55 million acres of mesquite, Oklahoma, three million acres of mesquite and there is probably a greater acreage in the states directly west. The terrain on which much mesquite is found and the dense tree type of growth of this wide spread range weed species makes ground application of herbicides costly and difficult. If and when aerial application of herbicides is devised for the control of mesquite you will have a field of service that will greatly expand your present sphere of operation. Are we doing anything to develop efficient herbicides and practical methods of aerial application for the control of mesquite? The Texas Agricultural Experiment Station, in cooperation with our Bureau of Plant Industry, has made great strides in this direction in recent years, and I am perfectly confident that in a matter of a few more years control of mesquite by aerial application of herbicides will be as fully developed and as practical as control of sandsage is at this present time.

Before leaving the possibilities of development of aerial spraying of range land I should mention several other of our major woody weed species that are receiving considerable attention from our weed control research men. In the Texas range area we have 18 million acres of cedar, 20 million acres of live oak, 16 million acres of creosote bush, 12 million acres infested with tar bush and approximately 9 million acres infested with shinnery oak. Elimination of these species with herbicides in being throughly investigated and as materials and methods are devised for their economic control, airplane application of the herbicides is certain to play a prominent part in the rogram.

A woody weed problem that is tremendous in both it's scope of area and relative size of individual species is one that extends from Texas and Louisiana through Arkansas and Oklahoma, well into southeastern Kansas—the hardwoods of the cross timber area. While blackjack and post oak are considered as the principle troublesome species in this area while, red, and holly oaks; persimmon, elm, ash and hickory; with an undercover of shrubs such as sumac, blackberry, buckbrush and vines, further complicate the problem and to a greater degree it's solution in controlling the mixed and variable species. At the present time I see little that indicates any immediate place for aerial application of herbicides in the control of mixed species in the cross timber area. In 1948 and 1949 a number of individual operators have made experimental applications in various volumes and using a number of available herbicides. I have inspected a number of these sites and found little to indicate that they had hit on the economic solution of the hardwood timber problem. Elwell of the Guthrie, Oklahoma SCS Field Station has made some real progress in his investigations with herbicides for the control of the cross timber species. His investigations to date, however, offer little that can be adapted to low volume aerial application. I am much less optimistic regarding the future of aerial appli-

cation of herbicides for the control of the mixed timber in this area as the depth of the foliage and consequent volume of spray needed for adequate coverage poses certain physical limitations that I do not feel the present spray plane and equipment can overcome.

In considering the range land and woody weed problems of Texas, Oklahoma, and other southern states as a future field of operation for spray planes we must not forget the limitations of operation that will be imposed by the hazards of cotton. Cotton is grown in much of the mesquite and cross timber area and the fact that cotton and 2,4-D do not mix is a matter that needs no further discussion here. The research people working on this problem are well aware of these hazards and limitations and are investigating every possibility that would permit of application of herbicides at a time when cotton is not growing. I might add that they have devised several methods of application of certain herbicides that control mesquite and some of these other woody species and which take advantage of the late fall, winter and spring season when cotton is not a consideration. Adaptation of these techniques to aerial application of the herbicides would be difficult to rationalize at the present time, but if and when winter or dormant treatment can be adapted to aerial application you will have not only an expanded field of operation but a much needed extension of your operational season.

In analyzing the data secured through the questionnaires sent to the States and Provinces in this area several trends or developments in aerial spray practices and equipment are indicated. The first of these is the almost universal favoritism developing for the light, ninety horsepower, monoplane of the Cub or Aeronca type as replacing the earlier favored war surplus Stearman biplane. Reason given for this change in plane type was in general the lower operational cost of the light monoplane. In areas of the northern and northeastern part of this region the monoplane is especially favored and indicated to be much more definite in application than the Stearman which tends, through turbulence created by the lower wing, to break up spray pattern and increase drift hazard. Any of us who have observed many types of planes in spray operations have noted that the monoplane operated at low altitude can actually apply the spray material to the foliage in a tree nozzle pattern; whereas, this can seldom be accomplished with a biplane having the spray boom close to the lower wing surface and in the orbit of it's turbulence. Operators who work in the sandsage area were, however, almost universally in favor of the Stearman for this type of work—indicating that it's higher load rating has an advantage in long hauls and high gallonage application.

Almost universally plane spray operators indicate that their planes are equipped with the newer light type of booms and light widely spaced nozzles. Almost without exception they indicate that this equipment is superior to the older, heavier type of boom with many close spaced nozzles. One of the largest and best operators in this area, however, indicated that he had, as a result of his experimental work, about decided to convert his booms to closely spaced nozzles of low volume as he believed he secured more thorough and uniform spray coverage with the latter type of equipment.

In past years I have merited the disfavor of many aerial operators in this area by consistently arguing for a maximum spray width of 45 feet. My recent survey indicates that you are now almost universally using this swath width in your operations. Several operators indicated that they had found a 60 foot swath width entirely satisfactory in treating easy to kill annual weeds in winter wheat, but that in preharvest treatment of wheat when these same weeds were more resistant they found it necessary to adapt a spray swath width of 45 feet or less. I am naturally pleased to note this swing to the more reasonable swath width and I am confident that it not only assures you of better coverage but markedly cuts the hazard of spray drift to sensitive crops and assures you of more satisfied customers.

The survey indicates a low accident rate with aircraft, a very low pilot fatality and a surprisingly low damage rate to crops reported in 1949. The low accident rate of aircraft engaged in aerial spraying reflects the excellent supervision and high licensing requirements of planes and pilots as administered by your local CAA. The almost insignificant number of reports of damage to crops as a result of aerial spraying in the area reflects the fact that aerial spray operators have been conservative, exceedingly careful and highly aware that we had a large number of pilots operating in 1949 that had no previous spray experience we can only conclude that the aerial spray schools and short courses such as you held here in 1948 have paid real dividends in the accomplishments of the pilots who sprayed 2 1/2 million acres in 1949.

The main objective weakness in aerial spraying development as indicated by the data which I have gathered, is the lack of intrastate and interstate organization for protection of your new industry through the establishment of a uniform code of ethics, legislation and financial protection. Aerial spray application of herbicides has developed like Topsy, "It just growed." As indicated earlier, aerial application of herbicides is practically barred from certain states and areas where fear of spray drift and lack of confidence in this method of application has developed a spray program based almost entirely on ground driven equipment. You have little or no well founded data available on most efficient spray swath width; on most efficient concentration of spray solution; most efficient type of spray plane and equipment and other factors concerned with aerial application of herbicides, to establish or refute arguments used for or against the practice. Several states have passed restrictive legislation governing the sale and use of 2,4-D that has stemmed invariably from aerial application of 2,4-D. Whether this legislation is justified or not, is established entirely on local observations and in many cases local predjudice. Your industry needs a closer organization within your membership to promote research and compile records; that would establish facts and data as an aid in protective legislation, as a guide in development of special agricultural spray planes and equipment, as a defense against local predjudice regarding aerial spraying

and establish the basis for an economical risk rate for insurance against loss of operating aircraft and damage suits of law.

Montana has in 1949 initiated a system of pilot and job record reports—combined with a follow up questionnaire sent to each individual for whom the aerial spraying was undertaken, that will furnish the type of information needed by spray operators throughout this area. They are securing complete records of all aerial spray operations and in addition will have comprehensive records of results of these operations. It would be well worthwhile for your State Departments of Agriculture and your State CAA officials to investigate the records that Montana is securing this year as a possible pattern for wider use. Bob Warden, Extension Agronomist, College of Agriculture, Bozeman, Montana, can give you details of their record system.

Among the questions asked in my survey questionnaire, was: Do spray plane pilots know weeds and weed control, crops and crop tolerance to herbicides, and herbicides? This is the only question on which I had no discussion in opinion—all reports indicating that the pilots were poorly informed on these important points. All pilots questioned elucidated this admission of lack of knowledge by the complaint of no source of information or schooling for the men who understandably have not had this training. As all Agricultural Extension and research people responded as did the pilots to this question it becomes apparent that we are criticising aerial spray operators for a fault that it is our responsibility to correct and that I am using time on this program that the pilots would rather have devoted to weed identification and a discussion of reaction of crop plants to herbicidal sprays.

Table 1. Acres treated by ground and plane application in 1949 in Mississippi Valley area and western Canada.

State	Acres sprayed (000)			
	Plane	Ground	Total	
	1949	1949	1948	1949
Minnesota	80	1600	—	1680
North Dakota	350	2487	—	2990
Soutsh Dakota	400	2600	1000	3000
Montana	150	1450	1800	1600
Nebraska	320	962	550	1282
Kansas	850	400	700	1250
Oklahoma	350	250	500	600
Texas	90	40	—	130
Iowa	150	—	1500	1500
Missouri	—	—	—	300
Wisconsin	5	195	300	200
Michigan	0.5	7.5	5	8
Illinois	100	900	600	1000
Indiana	—	—	—	100
Ohio	—	—	—	100
Colorado	400	400	120	800
Western Canada -1	30	8170	5500	8200

-1 — Alberta, Saskatchewan and Manitoba.

COST ANALYSIS OF AERIAL SPRAYING FROM ACTUAL FIGURES SUBMITTED BY OPERATORS

Prepared by Edw. G. Youngs

		Operator 1	Operator 2	Operator 3	Operator 4
Wages	Pilot	$.200	$.200	$.200	$.170
	Flagmen	.020	.025	.015	.020
	Other	.050	.050	.055	.040
Gas & Oil		.030	.035	.037	.032
Insurance	Ground	.....	.....	.014	.....
	Work. Comp.	.055	.012	.036	.....
	P. L. & P.	.....	.009	.037	.....
	Grd. Equip.	.005	.018	.006	.....
	Other	.....	.....	.....	.....
Repair & Mtce.		.020	.030	.015	.030
Depreciation	Airplane	.105	.020	.100	.050
	Sprayer	.010	.008	.050	.010
	Grd. Equip.	.015	.006	.030	.010
Booking Commissions		.100	.100	.100	.100
Total Fixed Costs		.61	.413	.695	.462
2,4-D Chemical		2/3 Pt. .550	1 pt. .760	1 pt. .750	2/3 pt. .500
Carrier	Fuel Oil	.....	.150	.145	.....
	Water	.050	.....	.....	.050
Total Chemical & Carrier		.600	.910	.895	.550
TOTAL COST PER ACRE		$1.210	$1.320	$1.590	$1.012

From Test Tube to Airplane Operators

L. L. Coulter

Many of the airplane operators who have been associated with chemical weed control for some time are no doubt familiar with the chemical nature of 2,4-D and its various forms. However, it might be well to review this briefly, particularly for some of the pilots who will be starting out next year.

The term 2,4-D is commonly used to identify the organic acid 2,4-dichlorophenoxyacetic acid. This acid is a white crystalline material which is highly insoluble in water and not suitable for commercial use until it is properly processed into one of several types of formulations which are sold commercially. The more common forms of 2,4-D are the esters, sodium salts, and amine salts.

Regardless of the formulation used the active ingredient is 2,4-D. This is usually expressed in terms of acid equivalent and the amount of this is usually indicated on the container label or the amount per gallon or simmilar unit. Since it is 2,4-D that does the killing it is important that you check the amount of acid which you are paying for.

The ester formulations are made by a chemical combination of 2,4-D and one of several alcohols such as methyl or isopropyl. This combination forms an ester which is soluble in certain oils and by adding an emulsifier to these oils a product which will emulsify in water is obtained. When an ester formulation of 2,4-D is added to water, the water takes on a white, milky appearance as a result of the emulsification of the oils. Presumably because of this additional oil and because of their ability to penetrate the waxy covering of the leaf, the ester formulations are particularly useful in the control of waxy leaved species and are used extensively for brush control and non-selective spraying. Esters do not have the same degree of selectivity on crops that the salts have and are not used as extensively for that purpose. The esters now in commercial production are more volatile than the salts and vapors escaping from open cans containing esters of 2,4-D or from areas sprayed with an ester may be hazardous to susceptible plants in adjacent areas. Several esters of lower volatility will be on the market next year.

When 2,4-D is combined with an amine such as triethanolamine, it forms what is frequently referred to as an amine salt, and this is highly soluble in water at most concentrations. Unlike the esters the amine salts are not soluble in oils and are relatively non-volatile. They are generally regarded as being intermediate between the esters and sodium salts in activity. Howver, they have sufficient activity for control of weeds commonly encountered in crop spraying and are particularly adapted for this purpose because of their high solubility and greater selectivity.

Unlike the esters and amines the sodium and ammonium salts are both powders. These powders are not so water-soluble as the amine salts and do not lend themselves to low volume spraying. These forms of 2,4-D are considered to be the least active of the three types of 2,4-D and also the most selective.

2,4-D is a growth substance type of herbicide. It moves through the plant to the roots, stems and leaves where its lethal action gradually causes death of the entire plant. In contrast some other herbicides such as the di-nitros and pentachlorophenol are known as contact herbicides. These materials kill plant tissue on contact and kill only the area covered. No appreciable movement of these materials to the roots occurs and regrowth of perennial plants may be expected. Contact herbicides are primarily materials for application with ground equipment except in such situations as pre-harvest sprays where they are used to kill weeds which if green would interfere with combining.

2,4,5-T is very similar to 2,4-D. It is formulated in essentially the same manner. However, its main use is for brush control where, of course, only the ester formulations are used. It is more active than 2,4-D on such species as brambles, osage orange, mesquite, and oak. Recent research in Texas has indicated the possibilities of controlling mesquite with 2,4,5-T. Similar success has been obtained in use against oak of the cross-timbered area. Various mixtures of 2,4-D and 2,4,5-T are now being sold for brush control. These have been very effective but often not as effective as 2,4,5-T alone.

Any chemical generally goes through a series of steps in the transition "from test tube to the airplane operator." Materials are first tested and screened for activity in the laboratory. Those which show promise are referred to chemists for formulation. Both the activity of the compounds and the type of formulation is then field tested and recommendations are established. For the most part 2,4-D and 2,4,5-T are either in this advanced field testing stage of development or are already under commercial use according to sound tested recommendations. However, there is frequently a tendency to avoid the time cosuming, expensive phase of field testing and begin immediately on a commercial scale with "something which should work". This is a common mistake which involves the consumer, the pilot and the retailer in an undesirable situation. Aerial application of herbicides is not a barnstorming proposition. It is a science requiring that the operator be as well grounded as possible in the technical aspects of the problem which he is undertaking to control. To equip himself as a technician in aerial weed control the pilot should consult with local agricultural authorities or with fieldmen of reliable commercial companies who are known to have carried out research on the problem with which he is concerned. It can not be over emphasized that success in aerial weed control depends on the sound application of the results from field testing by well informed pilots.

Selling — Contracting — Collecting

James Montgomery

SELLING

The industry of aerial agriculture is in its very infancy, therefore it has to be sold to the public. In many sections of the country aerial application has

not been accepted to any great extent by the farmers and growers. In a great many cases a farmer will sit back and let his neighbors try it out first, then after careful observation he might venture to try it himself. What we need for a sales point in this industry is actual proof rather than a lot of talk, and figures on paper that show the advantages which the farmer might gain. To most farmers, "seeing is believing," and I think the best method of selling is a job well done in a community, that all those in that section might observe and draw their own conclusions. If the job is done right, the proof is before their eyes and they will certainly fall in line with one of the greatest scientific strides that agriculture has ever made.

It is true that advertising in the local papers and over the radio is not to be overlooked, also have folders that give the story of chemicals and their application by air. The farmer can use it as a guide for his different crops and the possible infestations that might damage them. Always have a business card in your pocket to give out, and never be too busy but what you can have a few words to say to your customers. Crop spraying is somewhat a novelty in many sections and the more scientifically it is explained by an operator, the more readily it will be adapted. Explain that it is not as dangerous as many people are led to believe, that the pilots are all experienced and experts in their line, and that it is in no way an airshow. Another selling point is the fact that crops are not trampled by ground machinery which in most cases destroy about 4 per cent of the yield. The speed that application can be made by air is often the deciding factor on whether the crop can be saved or not, also your field is free from misses.

I believe that once aerial application is properly introduced into a community the largest part of your selling headaches are over, providing satisfactory work is continued. However, don't oversell your methods to the extent that a miracle is to be expected, but give the actual facts and remind the farmer that weather and growing conditions often enter in and that maximum results might not always be obtained.

CONTRACTING

I do not think it a good idea to contract too far in advance for work of this nature. There are too many things that can cause a contract to be broken, weather being the most common. The cost of materials is very likely to change, also, the loss of equipment may occur which would make it impossible to do the job at a given time. I contract nothing in advance other than government jobs which require a bid with an accompanying contract form. This state requires forms that each operator fills out and every month sends into the State Aeronautics Commission. These forms are in triplicate, one for the operator, one for the farmer, and one for the Aeronautics Commission. I use these as my contracts which do not tie me down to any specific time that the job has to be done. These forms contain all the necessary information that would be of any concern to either of the three parties mentioned above.

I believe an efficient method of keeping track of the work is to have a wall chart near the telephone. When a call comes in it is entered on this chart giving the name of the customer, location and acreage of the fields, type of crop, type and amount of chemical to be used, cost per acre, total cost, date and time sprayed, pilots name, and remarks. These are all in separate columns so that when a job is phoned in, the time of the call is entered along with the rest of the information. The pilot can easily find the information necessary for each job, which speeds up the operation considerably. When he completes the job he initials it and enters the time and date sprayed. This has proved very satisfactory when operating several units, as there is no confusion and it is always on hand for future reference. It also determines the problem of "who is ahead of who," as the time the call was received is put down, and it's "first there, first served." In my operation this method has proved very efficient and I intend to improve it by experience and systems used by other operators.

COLLECTING

Collecting has gotten to be quite an issue as the economic situation in this country is tightening down. I am setting up definite standards for next season and they are to be complied with or no work is to be done for that customer.

Cash on the barrel head as soon as the job is completed——or if in doubt about the person, before it is started——is my motto. If for some good reason credit has to be extended, there is an additional fee of 10c per acre. The farmer will sign a promissory note with interest at 6 per cent and I immediately put a lien on the crop. If the farmer is honorable and intends to pay, he should not object to this procedure. If he intends to get the work done and not pay, you are better off to lose him as a customer.

Very few operators are able to finance a season's expenses with nothing coming in from their work, therefore if the customer doesn't pay, the operator is going to have to borrow money and pay interest on it, which amounts to your paying interest on your customers' debts.

Several methods to collect are used, but I believe that you save time and money by having a man follow up on all jobs and make the collections or necessary arrangements in case of credit. Once a field is sprayed it doesn't take long before the farmer loses interest in the benefits that he has gained and as a result it is much harder for him to let loose of the money. I believe in immediate settlement, which is the time that his benefits show up the most prominently since this results in everyone being satisfied.

Getting to know your customers is very important as some of the larger farms and corporations pay all their expenses at the end of each month. I might suggest using discretion with the varied accounts and treat them in accordance with their own standards.

Sending out statements proves satisfactory in less than 50 per cent of the cases. They are too easily neglected and are paid only when convenient to the farmer, which might be several months.

In summing up everything pertaining to the operator, we can form this conclusion: operating expenses are heavy; we have to pay cash for our chemical, maintenance, gas, and oil, pilots, and equipment; it is either that we collect for our work as we go or we have to borrow money and pay interest which adds to

our already too high an overhead. Therefore we must, in order to keep the cost to the farmer down, have our money as soon as possible.

I might suggest getting cash for all jobs as soon as possible. If credit is to be extended make it so that it is profitable to you. Use discretion on your customers, as many of the larger ones figure thirty days as a cash transaction. If in doubt about a customer it is better to lose him than to lose money on him.

What a Good Spray Unit Should Do

L. E. Vaughn

There are many types of spray units using various designs and principles.

A good spray unit is a unit designed for all types of spraying and requiring a minimum amount of maintenance.

A unit designed for all types of spraying must have many built in features making it adjustable in output from 1 gallon per acre to 5 G. P. A., high and low pressure, positive cut off at the nozzle, no lag in starting to spray, a good agitation system and a pump capable of pumping wettable powders.

There are many problems involved in designing a unit capable of doing the many different types of spraying they are required to do. But it can be done. To have a light plane unit adjustable from 1 to 5 G. P. A., means the unit must be adjustable from 4½ G. P. M., to 24 G. P. M., figuring a 40 foot swath at 60 M. P. H. For the Stearman and N3N type the unit must be adjustable from 9 G. P. M., to 45 G. P. M.

The boom spray nozzle should start spraying at full pressure setting the instant the control is moved to the spray position. This is important in order to spray the first few yards at the start of each run. The shutting off should be positive the instant the control is moved.

The agitation system should be of a design that will agitate the fluid in each baffled compartment of the tank and not just a by-pass from the pressure regulator to one part of the tank.

The pump should be of a pressure type design that will permit the pumping of wettable powder.

Besides being designed with features for different types of spraying the unit should have additional features such as easy filling of the tank, tank quantity guage, tank and boom drain valve, pressure adjustable in flight, brake control on fan driven pumps, a well built baffled tank, no hose connections under pressure and a spray nozzle under the fuselage as well as under the wings.

To explain a few of the features: The filler cap should be of at least 3" opening for loading from large tank truck equipment and should be located on the outside of the ship for easy loading by buckets and cans on small jobs. The tank should have a guage to aid the ground crew in the proper filling of the tank and enable the pilot to know at all times how much chemical is in the tank.

The tank should be of a sturdy design built for field abuse and must be well baffled, with baffles riveted and sealed by welding to the tank skin.

The tank and boom drain valve is much needed for changing from one chemical to another.

The mechanical brake is a "must" on pumps driven by an air driven fan. Without a brake the pump will develop an excess R.P.M. when the tank is empty. The mechanical brake is preferred over the hydraulic type which has a shut off valve in the pressure line that causes a fluid lag on the pressure side and sometimes will develop excess pressure before the fan stops and in so doing damages the pump seals and gaskets.

Look for and insist on these features mentioned when you are considering the purchase of a spray unit and you men who spray will find that you will have a fairly trouble free unit that requires a minimum of maintenance.

A Viewpoint on Herbicide Research

Keith C. Barrons

My remarks will be confined to a viewpoint on a problem that is vital to the weed control industry and agriculture as a whole; the problem of bringing the field testing of new herbicides and basic research into better balance. With more fundamental work early in the development of an herbicide, field tests can be set up on a sounder basis and the accurate information needed by potential users obtained in a shorter time.

With 2,4-D we had the benefit of excellent work at Camp Detrick before much field work was conducted. With many of the newer herbicides, field tests have had almost exclusive emphasis. In working with TCA, for example, I have been acutely aware of our deficiencies in the fundamental information needed for a sound field research program which in turn is essential as a basis for sound recommendations. I am sure that such deficiencies are common to most of the newer herbicides.

For any new herbicide we need to know:

1. How it enters the plant. This affects application techniques.
2. The extent and nature of translocation.
3. Nature of selectivity. To what extent is it due to differential wetting, differential absorption, or physiological differences in reaction.
4. Importance of the physiologic condition of the plant as affected by growth stage and growing conditions before and after treatment.
5. Effects of external factors such as temperature and humidity.
6. If the herbicide acts through underground parts we must understand the effects of various soil properties and the soil environment including rainfall on absorption, on leaching, and on chemical and biological decomposition.

Perhaps this conference, through Project VIII of the Research Committee could promote and co-ordinate greater effort on fundamental problems by physiologists, and soil specialists as well as crop production people. Possibly a list of worthwhile projects prepared by the Research Committee would suggest problems of interest to graduate students. We in industry should do our part in bringing the overall herbicide research program into balance wherever we can.

Formulation in Industry

Wm. W. Allen

I cannot speak for all of Industry in the methods used for formulation and its problems, but I can give a general idea of the problems involved as seen from my work with A. C. P. Co. I do not believe our problems are much different from most of Industry or the methods used by us are at great variance from the rest of Industry.

The purpose of commercial formulation is to place in the hands of the consumer a product which is effective, uniform, storable, easy to use and more economical than could be made by the consumer himself.

Formulation starts when a new chemical is to be screened for herbicidal activiiy. The properties of the new chemical are first examined to see what type of formulation is best. A suitable solvent and carrier is then chosen regardless of costs to determine the herbicidal activity.

The formulators must be well acquainted with the problems in the field in order to make such a selection.

After the screening formula has shown the chemical to be of promise, a practical formula must be made for field testing. In making the practical formula the formulator must consider how the material is to be used in the field. If it is to be used in water solutions such as Na 2,4-D and amine 2,-4-D, its solubility must be determined and its compatibility with hard water considered. If it is to be used as an emulsion, the type of emulsifier compatible with hard water and solvents must be correctly chosen. If it is to be used in low cost petroleum oils, its solubility in these oils must be known. Sometimes formulations are needed of water solutions, water emulsions and oil solutions for the same chemical. This is the case with 2,4-D. Precaution must also be taken so that the products should be stable in storage, at low temperatures no separation should occur, it should not be corrosive to equipment, its toxicity low enough to be safe for men and animals and that the effectiveness of the chemical is not diminished by formulation.

To make a satisfactory formulation often thousands of formulae are tried to get the wanted results. Not only must the correct ingredients be used but the lowest cost correct ingredients must be found. Sometimes a herbicidal chemical resists all attempts to make a practical formulation. An example of this is a 2,4-D compound which when used under special conditions in our field testing showed up much better than any other form of 2,4-D yet it cannot, so far, be made into a marketable product. I believe it will be of value to the users of 2, 4-D to discuss the various formulations that are now made and give some thought as to what may be needed in the future.

The water soluble forms of 2,4-D are the Na salt and the amine salt. The sodium salt is not very soluble in water and for low volume spraying when 5 gallons per acre are used, difficulty is encountered in getting and keeping it dissolved. This results in clogged nozzles. The amine salts are in general very soluble in water. Various amines are used, some because they stand up better in hard water and need less sequestering agents, some because they need no special equipment for manufacture and some because of their low cost. There appears to be little difference in their action on weeds.

In the hard water areas both the Na salt and amine salts will be thrown out as low soluble salts of 2,4-D such as the calcium salt unless a sequestering material is added to keep these salts from forming or keeping them finely dispersed by a non-ionic surface active agent. In either case the amine solution will not then clog screens or plug nozzles. Amine solutions are not as effective on the hard-to-kill perennials and woody plants as the ester formulations, apparently because the amine-water solution does not penetrate the plant as well as esters of 2,4-D. They also appear to be less injurious on crops than the esters.

The more common water emulsifiable forms of esters of 2,4-D are made from either the ethyl, isopropyl or butyl esters of 2,4-D combined with an emulsifier and dissolved in a petroleum solvent. These formulations are more effective than the amine salts of 2,4-D on hard-to-kill perennials and woody plants. The main drawback of these formulations is their phytotoxic volatility. The damage from this volatility can be serious in localities where susceptible crops are grown such as tomatoes and cotton. In many cases they cannot be used and the less effective amine salt is substituted. New ester formulations are now being introduced with little or no phytotoxic volatility to cotton, tomatoes, beans, etc., and with as good or better killing power than the older esters.

It is well to point out at this time that the emulsifiers, cosolvents and oils have an important part in the effectiveness of 2,4-D. Some emulsifiers are better than others, this holds good for the cosolvents and oils also. This is a field for the future in which much work can be done in order to improve the action of 2,4-D.

The oil soluble form of 2,4-D is very effective for brush control, stump killing, sagebrush and mesquite control and low volume airplane spray on wheat. The emulsifiable ester formulation can be used provided it is soluble in the oil used. An ester dissolved in oil without emulsifier can be used provided it does not separate from the oil or crystallize in storage. Care should be taken to insure that the proper cosolvents are used to dissolve the formulation in the various kinds of oil encountered in the field. Esters with low phytotoxic volatility can be used in oil formulations when they are to be used near susceptable crops or an oil solution of 2,4-D acid can be used. Oil Soluable amine salts of 2,4-D, are very effective and much experimental work is being done in this line.

Surface acting agents such as the emulsifier, the cosolvent and oil play an important part in the oil formulation as they do in the water emulsifiable formulation. The choice of the right emulsifier, cosolvent and oil can make a more effective product for weed and brush killing.

It can be readily seen that the work necessary to make a satisfactory formulation can only best be done by trained technical workers who have the proper facilities, materials and field contacts. These workers are constantly searching for new materials to improve

their products and lower their costs. This in turn is passed on to the consumer who gets a better product at a lower cost.

Distribution of Agricultural Chemicals

R. L. Brandenburger

Everyone in the Agricultural Chemical industry, whether in state or federal work or with a commercial organization, has one common goal and interest—to serve to the best of our ability the "Boss". The "Boss" is the one who uses our Agricultural Chemicals—the farmer. We are all interested in his making money—as he prospers, we prosper.

The distribution problem—opportunity—is to serve the "Boss" with the right products at the right place at the right time with the right information so they are used correctly.

To render this service at a profit with mounting distribution costs is a challenge (freight increased 55 per cent to 79 per cent—warehousing increased 40 per cent to 60 per cent).

A product must go through the following steps to reach the "Boss" in the right manner—laboratory research, field testing, formula development, production, label clearance, packaging.

Distribution of product and "know-how" information to points convenient to the "Boss"—(Example: One company has 9,000 distribution points, 600 salesmen and 32 warehousing points.)

To serve the "Boss" properly products must be manufactured in advance of the season, investment and inventory risk taken. The additional risk of "competition" makes those in industry who want to survive put a better product at the lowest possible price in the hands of the "Boss"—Competition is welcome and is what has made this country great and strong.

Products should be priced to provide for service to the "Boss" that he deserves. If prices do not provide for this service, the "Boss" will suffer and industry serving him will suffer.

What can we do?

1. Voice your industry problems.

2. Get right information to the "Boss" so that your products are used correctly.

3. Give service to the consumer and prices with a reasonable profit to provide this service.

4. Find the facts by research,—(product formulation—manufacturing techniques).

5. Distribution — have the right product at the right place at the right time, with accurate use information.

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Those of us directly connected with distribution have problems, some of which I have enumerated, of which I am sure state and federal workers are aware. We, too, in the industry, are aware of the sincere efforts of those in state and federal work. Let's continue to work together doing a better job of distributing herbicides and Agricultural Chemicals in a way that will best serve the user, the "Boss" of all of us.

Problems Related to Industry — Sales

W. P. MacDonald

One of the most troublesome problems faced by the retailer is adjusting his stocks to the local demand. In weed control work, sales are directly affected by weather conditions—with poor crop prospects the farmer is reluctant to make an additional investment in his acreage. For a retailer to anticipate his sales so that he can approximate them with his supplies has been complicated in recent years by the fact that chemical prices have frequently been reduced during the selling period. Consumers reason with considerable justification that if they delay their purchase the price will be more attractive. This has not only worked a hardship on the individual retailer, but has had an adverse effect on the entire industry. Many potential users have delayed their purchases until the last minute expecting more favorable prices and the result has been that when they came to buy, they found the local stocks depleted and they were unable to spray. For the benefit of the entire industry it is highly desirable that in future seasons all important price changes be established well in advance of the selling season which ordinarily begins in volume during the month of March. If prices are established early, sales can begin early. Early sales would not only help the retailer but would have a beneficial effect on the industry all the way back to the manufacturer.

In order that he may know where he stands on sales, the retail outlet must adopt a firm policy with regard to the return of merchandise. The purchaser should be able to anticipate his need sufficiently close so that this should not be a problem. However, if the retailer over sells the user, sooner or later he is going to have a problem with returned goods.

From the standpoint of retail sales, we believe that the manufacturer and formulator have done an excellent job with regard to uniformity of product. However, there continues to be an occasional can which is unsatisfactory. These bad cans are not discovered by the retailer and are called to his attention only when he hears from the consumer. Perhaps they are not filled to capacity, contain foreign material, or simply have gone out of condition. Of course, they can always be replaced by the retailer and returned to his distributor, but they do not enhance the reputation of the seller. Anything that can be done to further reduce this problem will be a distinct help.

The retailer and distributor have a mutual problem in avoiding expensive carry-over inventories. It is their joint responsibility to anticipate the local requirements so that the retailer can clean up his stock at the year's end. This has been particularly important with 2,4-D in view of the frequent formulation and price changes.

Unethical, fly-by-night salesmen and even some local merchants have plagued the 2,4-D business as they have most other lines. In order to cut prices, and in spite of legislation in most states to the contrary, some retailers have ordered 2,4-D in bulk and then poured it out into the farmer's own containers in order to give the purchaser the benefit of the quantity

price discount. South Dakota and possibly other states, prohibit this practice except by licensed pharamicists; nevertheless it exists. It has also been true that on many occasions unreliable salesmen operating from their automobile have fast-talked farmers into placing substantial orders with them. This has been done with no intension of ever returning to check on the results obtained or to give the farmer any other kind of service. Of course, this kind of competition can be met only by aggressive and reputable dealers.

The local dealer owes it to his trade to be informed on weed control practices. This responsibility is shared by the distributor to whom he must generally look for advice and council. He should be in a position at all times to inform his trade on changes in recommendations which, due to weather conditions or other factors, are frequently necessary right in the middle of the spraying season. Dealers who obtain regular news letters from their distributors are generally much better informed than are their competitors who are forced to rely on their experiences during the season. The entire chemical industry must keep in mind that the local dealer is the man on the firing-line and is actually considered by the consumer to represent the entire industry. Anything that can be done by the distributor, the formulator, or the manufacturer to help him with his problems will be beneficial to all.

Sales Problems — Chemical Control of Woody Brush

J. F. Allen

1. KNOW WHAT TO SELL.

I can't think of a more appropriate time or place to express appreciation for the work of the research and development people who have contributed so much to the general fund of knowledge on the subject of Brush control by chemical methods. In this group I would include not only the men who work in the various colleges and experiment stations, but also those who are engaged in the commercial field. Without exception I think they have been both earnest and honest in their devotion to the task of developing a new industry and at the same time safe-guarding the consumer public.

In our particular field, which is primarily the control of undesirable brush and foliage growth along and under power and telephone lines, either along the roadside or through private right of way, we have a very large potential market for chemicals, equipment and "know-how." There are also plenty of hazards to avoid. Utilities have devoted years of effort and millions of dollars to build a satisfactory service and develop public good will. Irresponsible actions of a single man armed with a piece of spray apparatus and a lethal chemical can destroy in a day that which has taken years to build. Thanks again to the research men, we have at our command the answers and the precautions we need and if we encounter new problems as we go along I'm sure they will be just as willing and just as capable as they have been before. The choice of the materials then can best be made by determining, first, what does the customer want to accomplish; second, what chemical or combination of chemicals will do the job in the best and safest manner and third, but not always last; what will it cost?

2. WHEN TO SELL.

There is a saying that the time to do it is "now". But a well planned program of chemical brush control takes a lot of preparation and the better we do the preliminary planning the more successful and satisfactory we may expect the job to be. Certainly it is easier to appreciate a brush and foliage problem in the summer when the leaves are on, and a year is not too much time to have to work out a well integrated program.

3. WHERE TO SELL.

Anyone who has a brush problem, regardless of the methods he may have used in the past, may be a prospective customer for Chemical Brush Control service. The extension of electric and telephone service to millions of new rural customers involves the building and maintenance of many thousands of miles of pole lines and every forward step in improving the service delivered over these lines calls for improved clearance and freedom from foliage interference. It is our job to devise better and cheaper methods of providing this clearance and then to explain these methods to the man who buys it.

A skilled workman with a spray gun in his hand can reach farther faster and more effectively than the common laborer with only a brush axe at his command.

Application

George Martin

Four key words are of importance to the custom operator as well as to all concerned in the battle for weed control. These are faith, knowledge, experience, and improvement. The commercial operator must have faith in control, must be willing to learn and use his knowledge, and through his experience bring about improvement. He must also be reasonably sure he can finish the job he contracts to do with good equipment and without careless application.

Since the world today demands new ideas and methods, the commercial operator must continually increase his knowledge through personal experience, problems encountered, and information gathered from the literature and conferences such as this. The county authorities should also be consulted on applications within their area.

The equipment used by the applicator should be the best he can possibly provide with any accessories or adaptations desirable to produce satisfactory results.

In this way, improvement, gained by experience and through knowledge and faith, can be translated into action.

Application

Ernest Moser

PROBLEM 1

Choose your area:

Any firm engaged in the aerial spray business should stay at home if possible. I realize all areas are not suitable for using 2,4-D due to congested conditions by population or susceptible crops. If it is necessary to choose a base of operation away from home, the operator should plan a long range advertising campaign, and also work toward proper public relations in this area. He should decide on the size of operation he is going to work, and work this one area instead of moving from place to place.

PROBLEM 2

Selling:

Do not over-sell. Probably more over-selling has been done in this line than any other product ever put on the market. The farmer should be told exactly the results to be expected as near as you can honestly tell. If the results are somewhere close to those expected, adjustments will be unnecessary and the farmer will feel he got his money's worth.

Checking each field before and after spraying will greatly reduce the possibility of dissatfaction on the part of the farmer. By checking before spraying, you can judge the proper amount of chemical to use and by checking after spraying you are able to see results obtained which will put you in a much better position to judge results expected on the next field of like condition.

Don't over-sell—check your results—and make proper adjustments, if necessary.

PROBLEM 3

Number of persons on each crew:

I feel a spray unit should consist of two airplanes, one tank wagon equipped to load chemical and carrier into the planes. This tank wagon should provide sufficient reserve storage to prevent stoppage of work during the day. 500 gallons for each airplane should be the minimum. The crew should consist of at least two flagmen, one tank wagon man, two pilots and an advance man whose duty it would be to contact farmers regarding spray jobs, checking results, making adjustments and collecting for work already done.

PROBLEM 4

Public relations with research and technical men:

These men will be our best salesmen to show what results are obtained in the field. Operators should work very close with county agents and weed supervisors. Sell these men by doing good work and not overselling.

PROBLEM 5

Streamlining our operation:

At the present we are returning to the farmer around $8.00 in return for every dollar he pays us. We must now streamline our operations so we can show a profit at present prices. This can be done by using time savers such as a flow meter (which has not been developed) and by ground to air communication.

An Equipment Manufacturer's View of Weed Control

C. S. Moppison

The farm equipment manufacturer is interested in weed control for three reasons. (1) He desires to manufacture the required tillage and chemical application equipment for the weed control operations. (2) The equipment manufacturer is vitally interested in encouraging the use of the best accepted agronomic practices because a prosperous farmer is the best sales prospect for any new equipment. (3) The weed control methods accepted as most efficient may influence the design requirements of machines for seedbed preparation, planting and harvesting.

A comprehensive list of the field requirements which the equipment engineer must evaluate in order to develop an efficient weed control machine is presented.

Disagreement among research and extension representatives as to the proper use of herbicides has at times been highly confusing to both the farmer and the equipment manufacturer. More efficient application equipment can be manufactured at lower production costs whenever more reliable requirements and recommendations are established. This should be mutually beneficial to the farmer, the chemical industry, and the equipment manufacturer.

The Problems of the Equipment Manufacturer with Relation to Weed Control

W. L. Lambert

Many equipment manufacturers, either now in the equipment business or anticipating going into the equipment manufacturing business for weed control machinery, I think, have three pretty basic problems they need to answer for themselves in this field. These are:

1. What market are you after?
2. What are all of the uses for a sprayer in this market area?
3. What is the price range that farmers will pay or users will pay for equipment to do their specific job?

1. What market are you after? There is a wide range over which spraying equipment is needed for weed control, and each area presents in a general way its own specific requirements for weed control equipment. For example, the equipment best suited for the wide expanses of grain producing territory is vastly different than the requirement for equipment for the smaller Iowa general purpose farm. The requirements for the specialized job of weeding cotton are vastly different from the equipment needed for spraying wide expanses of range land in the southwest. The specialized job of spraying weeds along railroad right-of-ways is vastly different from

the equipment needed for weed control in vegetable crops.

The manufacturer is faced with the alternative of building a rather highly specialized piece of equipment for a highly specialized job, or he is faced with the problem of building a great number of different models in his line and offering a complete line of spray equipment.

2. What are all of the uses for a sprayer in any market area?

Weed control is only one of the jobs that the normal operating farmer would do with a piece of spraying equipment. This is particularly true in a good many of the general farming areas. A rancher might only spray weeds in range country, or the grain farmer might only spray weeds in small grain, but a general farmer will have a number of uses he wishes to make for the same piece of equipment. He will probably want to do some insecticiding; he may want to spray his cattle; he may have a few fruit trees that he would like to spray; or he might want to whitewash his barn. If the piece of spray equipment is not suited to a wide variety of jobs, he may deem it an undesirable piece of equipment for his farm.

3. What price will the user pay for the equipment?

It is highly possible to build most any kind of a piece o fequipment if there is a readily available market for this equipment. Many advances could be made on sprayers today if it were not for the limitations on the price in the field.

In general, the spraying industry is new enough that it is almost impossible for the manufacturer to design equipment broad enough to do all of the farm jobs. Neither does the farmer, on the other hand, have any appreciation of what constitutes adequate equipment to do his many jobs. A great many people have led the farmer to believe that a very inexpensive and altogether inadequate piece of equipment is adequate for doing a wide range of jobs.

In general, a sprayer today is one that is either built for a specialized purpose and is a specialized piece of equipment, or it is made up of a series of compromises to enable the farmer to do as broad a job as he possibly can with his piece of equipment.

After the manufacturer has figured out the market that he is trying to reach, the uses of the sprayer in this market, and the price range, his equipment will probably either be designed to become a high-pressure sprayer or a low-pressure sprayer. Both have specific advantages or disadvantages, depending on the job that they have been designed to do. Both have a definite place in the spray industry, and both are widely accepted by the users today.

Sprayers are made in a large variety of different types. Probably one of the most recent and one of the most widely used for weed control is a tractor mounted power-take-off sprayer. This unit has the advantage of being cheap to build; for certain jobs, it is entirely adequate, is and will continue to be widely sold as one type of sprayer.

To overcome some of the disadvantages of the power-take-off type of unit, many manufacturers have gone to another type of unit—the trailer type. In the grain area, these trailers can be built with fairly low clearance. In the case of a trailer unit, the boom can be either mounted on the tractor or trailer. However, in most cases, to answer the objection of having to mount and remount the sprayer on the tractor, the booms are attached to the trailer, making a complete unit with adequate means for carrying solution.

If the manufacturer is going after the market in row crops, then normally this trailer must be of relatively high clearance—at least clearance as high as the tractor axle. It must have either an adjustable tread or a wide enough tread to follow a row crop tractor through the average crop rows. In some cases, the manufacturers have tried to design an adjustable axle which would take in both the low trailer and the high trailer and have that axle adjustable for either a narrow tread or a wide tread. This would seem to be a move in the right direction; however, it does add a cost to the machine and probably would penalize the purchaser who would need only a simple standard type of axle. These two types of machines —both the low trailer and the high trailer—are coming more and more into popular demand. However, they are more expensive in general than the power-take-off unit and the individual requirements of the farmer dictate pretty much the type of machine he should have.

In the case of a number of these trailer units, there comes a question of how should the unit be powered. In some cases, they are powered direct from the power-take-off of the tractor, and in other cases, they are powered from a motor connected to the unit. If the motor is connected to the unit, then the sprayer becomes a complete unit separate from any power requirements from the piece of equipment used to pull the machine.

The third category of spraying equipment is a high-clearance, self-propelled piece of equipment. One or two manufacturers have been working on such a piece of equipment for the past five or six years; others have come into the field quite recently. Up to now, the high-clearance, self-propelled has been pretty much a specialized piece of equipment built to do a specialized job. With more emphasis being put on weed control in tall corn and with an increased second brood of corn borer infestation over a wide area in the central part of the United States with additional weed work on sugar cane and high growing crops, more and more emphasis will continue to be placed on the high-clearance, self-propelled equipment.

After the manufacturer has determined the type of equipment he wishes to manufacture, he still has the consideration of the type of boom he wishes to use on the equipment, the type or method used for propelling the spray material from the tank to the nozzles, the type and capacity of nozzles he wants to use, and the filtering systems to be used on the sprayers. There are a number of different manufacturers of nozzles; the same is true of filtering equipment, pressure regulators, and other spray accessories. Those selected by the manufacturers will be those that best suit the program in the area in which he is going to operate and the price range in which he intends to build the piece of equipment.

I think most of us in the equipment manufacturing business have the obligation of field testing spraying equipment for one or two years and mak-

ing any refinements that need to be made on the piece of equipment before it is merchandised to the farmer. A very common complaint made by farmers is that the equipment has been inadequate for the job. We have heard of equipment breaking down before even the first acre has been sprayed or before one season of use has been completed. This simply means that the manufacturer has not adequately field tested the unit. Perhaps he has sold a piece of equipment in an area where it was not adapted to the job at hand, or he has not seriously considered all of the jobs that the sprayer would be called upon to do in a given area. More often the unit was too cheaply constructed to satisfactorily do the job that it was called upon to do.

In conclusion, it would seem that the team of weed control is a cooperative team made up of the chemical manufacturer, the spraying equipment manufacturer, and the research people. It is the job of the chemical manufacturer to manufacture and test the best possible formulation of weed killer. It is the obligation of the equipment manufacturer to manufacture good sound equipment adequately field tested before being offered for sale. It should be the responsibility of the research people to test out and recommend the chemicals made by the chemical manufacturer and the equipment made by the equipment manufacturer that will do the best job for the consumer. Only by having close cooperation of these three groups will weed control move ahead at the pace at which it is capable of moving.

Control of Woody Plants

Glenn Viehmeyer, Presiding

Chairman, L. W. Melander

Glenn Viehmeyer, Vice President of the North Central Weed Control Conference, called the meeting to order and introduced program chairman L. W. Melander, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Minneapolis, Minnesota, who then took charge of the meeting. Approximately 350 people were in attendance.

PANEL DISCUSSION

Status of 2,4,5-T in Relation to Woody Plants

Chairman, J. W. Zahnley, Kansas State College, Mathattan

T. A. Ashbaugh, West Pennsylvania Power Co., Pittsburgh

C. E. Fisher, Texas Agricultural Experiment Station, Spur

Dayton Klingman, Bureau of Plant Industry, Soils & Agricultural Engineering, U. S. Department of Agriculture, Lincoln, Nebraska

D. A. Savage, United States Southern Great Plains Field Station, Woodard, Oklahoma

E. D. Witman, Sherwin-Williams Co., Cleveland, Ohio

Dr. Melander announced that due to illness and other factors, some of the personnel of the first panel discussion were unable to take part in the program. Chairman J. W. Zahnley was unable to talk, while Messrs. T. A. Ashbaugh, D. A. Savage, and E. D. Witman had been unable to get to the conference in time for the program, Mr. C. C. Butler of the Bureau of Reclamation, Department of the Interior, Billings, Montana, and Mr. Ralph Kaufman of the Espelundt Tree Expert Company kindly agreed to "pinch hit" on this panel. Program chairman Melander took over the chairmanship of this panel.

Mr. Butler discussed the progress made in eradicating woody plants on drainage ditches in the western states. He also cited some experience with helicopters using 2,4-D and 2,4,5-T. Mr. Kaufman, who has had extensive experience in killing woody plants on rights-of-way, stated that 2,4,5-T had a definite use in the eradication of woody plants but that it was limited to those plants that it would kill and those that 2,4-D would not.

The following is a resume of the reports sent in by the members of the panel previous to the conference.

Abstracts of the panel discussion on the status of 2,4,5-T in relation to woody plants.

Working at Spur, Texas, C. E. Fisher and Dale W. Young report effective results with 2,4,5-T applied to mesquite by both airplane and ground equipment. Best results were obtained when treated in the full leaf stage of growth. Airplane application of 2/3 pound of the ester of 2,4,5-T in four gallons of 50% water in oil emulsion gave best results. Applied by ground equipment one pound of the ester of 2,4,5-T in twenty gallons of water in oil emulsions seemed best, the emulsion being superior to oil solution. Similar applications of 2,4-D were not effective.

Basal applications: Effective results were obtained by wetting the bark around the base of the mesquite plants with a 0.5 per cent solution of 2,4,5-T ester in oil. Similar applications in water and water-oil emulsion were not effective. Mixtures of 2,4-D and 2,4,5-T in oil gave results commensurate with the amount of 2,4,5-T in the mixture.

2,4,5-T was likewise more effective than 2,4-D when applied to the cut surface of the stumps of mesquite.

Dayton Klingman at Lincoln, Nebraska, found 2,4-D to be more effective than 2,4,5-T on buckbrush. One and two pounds of 2,4-D ester gave 65% control while 2,4,5-T at the same rates gave only 2% control. On the other hand 2,4,5-T gave 90% control of osage orange while 2,4-D gave only 10% control.

D. A. Savage at Woodward, Oklahoma, reports that sand sagebruch *(Artemisia filifolia)* may be controlled and 50 to 90 percent of it eradicated by one proper application of 2,4-D in May when the plants are growing actively. Per acre rates of ¾th pound of the ester form of 2,4-D or 1 pound of the amine or sodium salt forms are required. The ester forms may be applied in 3 gallons of oil or 4 gallons of water and 1 of oil per acre. The latter emulsion is suggested for use in applying the salt forms of 2,4-D. Sagebrush is much less susceptible to 2,4,5-T. Shinnery-oak and mesquite, however, are more susceptible to

2,4,5-T than to 2,4-D. There were no indications that combinations of 2,4-D and 2,4,5-T were more effective on woody plants than either product used alone.

The discussion by Dr. E. D. Witman of chemicals for brush control is summarized in the following significant statements:

When controlling insects of fungi, it is common to employ one chemical at a time to kill off a uniform population of pests. It is doubtful if herbicides ever may be similarly handled since the pest (weeds or shrubs) are very seldom uniform. Therefore, instead of applying a single chemical as we do for controlling insects and fungi, we are forced to apply a mixture of several chemicals to gain control of a diversified plant population problem. For the above reason, both 2,4-D and 2,4,5-T have a definite place today and will probably keep a definite place in the future in the woody plant herbicidal program. It is to be expected that other active ingredients will be developed in the future and these too will be mixed in one product to get maximum control.

A further problem in the control of brush and woody plants revolves around and the completeness of foliage coverage and penetration with a minimum of carrier (liquid or solid). The solution to this problem will be found in exacting formulations in which so called inert ingredients such as wetting penetrating and dispersing agents are properly balanced.

PANEL DISCUSSION

Present and Future Status of 2,4,5-T Brush Control of Pastures

Dayton L. Klingman

Brush in pastures include many species such as buckbrush, sumac, the locusts, and briars. Also, many of the common trees spread into pasture areas from boundary lines, drainage areas, etc. and compete for light, moisture, and nutrients, thus reducing the production of forage in the pasture.

Often times brush control operations should provide for methods of removing the brush from the land so that reseeding may be accomplished, or grazing can take place more readily. Where this is desirable the mower most certainly has a place for smaller brush on accessible land. Heavier brush may be removed by other equipment. In all cases the grazing should be adjused to favor vigorous growth of grasses.

The growth regulators have great promise as aids in controlling many brush species. If the brush species found in the pasture are all susceptible to 2,4-D (buckbrush, sumac, black locust, etc.), 2,4-D materials only should be used rather than the more expensive 2,4,5-T. If the species are not susceptible to 2,4-D but are susceptible to 2,4,5-T such as Osage orange, wild rose, wild blackberry, and wild raspberry, 2,4,5-T should be recommended at least until the value of 2,4-D in mixtures with 2,4,5-T is more adequately evaluated. For example, buckbrush (*Symphoriocarpos occidentaiclis* Hook.) was sprayed with one and two pounds of 2,4-D ester and 2,4,5-T ester in 1948. 2,4-D at these two rates gave approximately 65 per cent control as determined the year following spraying. 2,4,5-T at these rates gave estimated control of less than 2 per cent, or in other words no control (did kill some above ground parts of plants). On the other hand more than 90 per cent top kill of Osage orange was obtained with 2,4,5-T, while 2,4-D gave less than 10 per cent top kill. If there were a mixture of the two above groups of species, then a mixture of 2,4-D and 2,4,5-T would clearly be advantageous.

There is often concern about the eradication of worth while legumes and other species by a spray program in pastures. Where these species occur in abundance, the individual landholder will have to decide (1) whether the brush is doing damage to more than offset the good being done by legumes, (2) cost and effectiveness of other control methods, (3) possiblity of survival or re-establishment of good legume species (naturally or reseeded).

Advantages and Disadvantages of Different Methods of Brush Control

Harry M. Elwell

Before discussing the advantages and the disadvantages of different methods of brush control, it should be clearly emphasized that satisfactory procedures have not been well established. In fact, more research is needed, not only for determining the most effective methods and times of application, but also the ultimate capacities of herbicides and the best chemicals for a particular use.

However, the method that is used for controlling brush must fit the land. Problems of brush control and pasture development will vary greatly because of the wide range of woody plants, grasses, climatic and soil conditions. And the success of the pasture will depend largely upon the management after the brush is removed.

The soils covered with scrubby oak in the Red Plains are usually shallow and highly erodible if not protected by good vegetative cover. It is, therefore, important that a continuous protective cover be maintained on this land.

EROSION CONTROLLED AND SATISFACTORY PASTURES PRODUCED

Where selective herbicides are properly used the land cover is not destroyed but the brush and sprouts are killed. Leaves, twigs and stems of Black-jack and other oak brush sprayed with mixtures of 2,4-D and 2,4,5-T all accumulated in a mulch on the soil at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma. There was an average of 7,593 pounds per acre of litter that remained on the soil two years after treatment. However, herbicides have often given erratic kills of woody plants and are not equally effective on all species.

The mulch conserved water and made conditions ideal for the growth of the grasses. They grew largely from the few spindling plants intermingled in

the brush. The yield of grass in 1949, as calculated from clippings, was 2,836 pounds per acre from the plots sprayed in 1947. This yield was equal to that of virgin meadows. Another material commonly known as Ammate (ammonium sulfamate), when used at a strength needed to control the brush had unfavorable effects on the native grass.

A good stand of grass is more effective for erosion and flood control than the original sparse cover of brush and grass. In fact, runoff measurements made the last eight years show that 45 per cent less water ran off annually from good grass on cleared land than from an adjacent area of brushland. Production of grass was increased five times by removing the brush. Cleared land has produced an average of 66 pounds of beef per acre during periods of summer grazing the past six years.

MACHINES FOR REMOVING BRUSH

The first brush control work on the Red Plains Station was done with hand tools in 1935. Since then, various machines have been tried, such as saws, cutters, mowers, crushers, buck rakes, etc. In general, the brush was cut and removed satisfactorily. However, sprouts from the stumps were difficult to kill. They were controlled by annual mowing but, after 14 years, many remained.

EQUIPMENT FOR APPLYING CHEMICALS

Equipment for applying chemicals for brush control is being studied. When treating areas adjacent to susceptible plants the drift must be controlled.

The hydraulic-type sprayer has given fair results in applying chemicals with large volumes of water. Pressures of 100 pounds or less have performed best. In a preliminary test in July, 1948, on the Red Plains Station, an air blast sprayer also gave good control on scrubby oak. Only 50 gallons of liquid and 100 pounds of ammonium sulfamate (Ammate) were used per acre. The hydraulic-type spraying machine, under comparable conditions and control, required 300 pounds of Ammate and 300 gallons of water per acre. The wind current developed by the air blast machine seemed to create sufficient turbulence of the leaves and twigs to allow wetting with only one-third as much Ammate and one-sixth as much water as the hydraulic equipment.

Several tests have been made with the airplane. It offers great possibilities for large scale applications. The irregularity of both the topography and the heights of the woody plants makes it almost impossible to fly at a uniform level over the brush. However, a few aerial applications on oak brush have been observed that appear to be rather encouraging. In some tests in 1948, and also in 1949, brush and trees from one foot to 20 feet in height were 85 per cent effected by one application. It appears highly probable that an effective and practical technique of air application may be developed for controlling woody plants in pastures and ranges.

After the brush has been deadened, it remains standing for a considerable time if not broken or crushed down. A heavy stalk-cutter type machine has been used for this purpose the second and third years after applying the chemicals. It crushes the dead material and forms a mulch on the surface of the soil which conserves moisture, improves fertility, and favors the growth of grass.

"Can We Now Recommend a Twelve Month Spray Program in Woody Plant Control?"

L. M. Stahler

The men preceding me on this panel have given you a comprehensive discussion of latest developments in specialized fields of woody plant control indicating from their observations and experiences the efficiency and development of the possibilities of control of brush and trees throughout the season. From their discussion it is evident that herbicidal materials and application techniques in this field have been greatly improved and enlarged in scope the past few years. It is further as fully evident that we need a lot of concerted and intensive investigations with herbicidal materials, and methods and dates of their application in order to fully develop the field of woody plant control on a year round basis.

We were fortunate to have Dr. Allen of the American Chemical Paint Company to discuss the control of woody plants on roadways, right-of-ways and along power lines, as he and his associates are leaders in this field of development and enterprise. It is in this special field of brush control that the effective spray season has been most greatly extended through the development of the use of dormant sprays of 2,4-D and 2,4,5-T applied in oil as a cut surface or stump treatment. In addition to extending the working season the development of these techniques is highly advantageous in that it evades the hazards of 2,4-D and 2,4,5-T to susceptible crops and vegetation commonly growing adjacent to highways, right-of-ways, and power and communication lines.

Mr. Day of the Dunbar Forest Experiment Station of Michigan in his discussion brought out the fact that the effective spray season for control of undesirable trees and brush in the Great Lakes Forest area is at the present time limited to a relatively short period during the active growth of the hardwood species. Woody plant control for the release and improvement of desirable species stands in this area as a winter practice has the additional handicap of heavy snow fall which hampers movement of men and equipment. He indicated that under certain limited conditions the use of basal dormant sprays, or cut stump treatment, with the new herbicidal formulations offers some possibility for winter application, but that in general this practice was poorly defined by available data and little developed in use. He brought out the important point that the desirable coniferous species in the northern forest area had shown a markedly higher degree of tolerance to 2,4-D and 2,4,5-T in mid and late summer season, which fact delimits even summer season applications—especially in using these herbicides for the control of undesirable species for the release of seedling conifers.

Dr. Hanson of the Minnesota Experiment Station, in considering developments in control of brushy weed species in northern pastures—a tremendous problem; indicated likewise a real need for research and information to improve the efficiency of even the restricted short season spray operations now recommended. He emphasized that we do not at present have the satisfactory techniques and herbicides for efficient control of our northern buckbrush and prickly ash, and that even hazelbrush which is considered quite sensitive to 2,4-D requires repeat applications in order to secure a satisfactory degree of control or elimination. Dates of application for efficient control of these species have not been critically established and there are few data to indicate that dormant fall, winter or spring applications are feasible. Development of this practice would be well accepted on the basis of the fact that labor available on the average farm during the non-crop season would make this practice in use highly economical.

Mr. Coulter of the Dow Chemical Company has well reviewed developments in chemical control of woody plants in an area of which he is well familiar —the range land of the Southwest—a problem which in extent is the greatest woody weed problem that we have. Some seventy-two million acres of range land are estimated to be infested with woody weeds which limit forage production in this area. Control of sagebrush on a practical field scale basis as a result of the research and developments undertaken at the Woodward, Oklahoma Station touched off the interest in this field. As indicated efficient control of sagebrush by herbicides is at present limited to a relatively short period of application, and there is no indication that the effective spraying season can be extended beyond the early full leaf period of development. Mesquite, presenting the greatest range problem today, has as yet been insufficiently investigated to permit of general field scale recommendations for use of herbicides. The research on this problem at the Spur, Texas Station in the past few years has, however, opened an entirely new field of hope for efficient control of this species through the use of herbicides on an economic basis. Results of the investigations at Spur would indicate that techniques will be developed to permit of a diversified and perhaps twelve month program of control. In no other field of woody plant control is research more highly intensified and more specifically undertaken than the investigations now under way at Spur, Texas for the control of mesquite. Research and interest in the control of the mixed species of hardwoods infesting the range land of the cross-timber country has been pioneered by Elwell of the Guthrie, Oklahoma Station and his development as well as those of others are yielding data which represent real progress in the development of techniques and materials for herbicidal control of the cross-timber woody species. Data now available indicate the practicability of dormant applications of 2,4-D and 2,4,5-T used either as a basal treatment or over-all treatments. These developments are particularly noteworthy when we consider that they can be undertaken during the slack winter season when labor is cheaply available and the cotton hazard of the area nonexistant. Coulter indicated his satisfaction in results of aerial spray applications as a full foliage treatment, and on the basis of his experience foresees development of technique and materials that promise efficient and satisfactory control of the mixed timber of the area as economically acceptable on the basis of increased forage production.

Looking at the entire picture as presented in this forum, the need for additional and accelerated research programs on the control of woody plant species cannot be overemphasized. It is quite evident that with 2,4-D and 2,4,5-T formulations we could, with the development and application of new or improved techniques or methods, rates or dates of application; economically control most of the woody species that hinder the development of desirable forests, infest and interfere with the maintenance of highways, right-of-ways, power and transmission lines, and limit the production and complicate the management of millions of acres of our pastures and range. Developments by commercial manufacturers during the past year promise newer and even better formulations of these herbicides and with the development of the techniques resulting from the intensive research program of which you have heard, there is a certainty that we will eventually undertake woody plant control on a twelve month basis and that this undertaking will be a highly specialized and technical commercial development.

Killing Woody Plants on a 12-Month Spray Schedule

R. H. Beatty

In discussing a 12-month spray schedule for roadside and power lines, I am limiting my remarks to our observations of 2,4-D and 2, 4, 5-T sprays applied under eastern conditions. The subject has two major aspects—killing brush in its growing stage, and killing brush during the dormant part of its life cycle, whether it has leaves or not.

Briefly, we have four methods of approaching this problem with regard to treatment. The first is an overall spray, high volume, using water as the carrier; the second, an overall spray, low volume, using oil as the carrier. The third is the treatment of cut stumps with oil or water as the carrier, and the fourth approach is basal treatment with water or oil as the carrier.

I will not take the time to describe the use of the high volume water spray or the low volume oil spray because technical papers have been reported to the Conference on concentrations of chemicals, nozzles and the species of brush these treatments will control. However, I would like to report that progress is being made by using oil-water emulsions and by adding various materials which aid in penetration and translocation.

It does not seem practical for a person to say one method is superior to the others unless the type of terrain, species of brush to be controlled, and height and density of brush are considered.

When treating brush in the leaf stage, it may prove

best to use a water spray containing a mixture of 2,4-D and 2,4,5-T the first year, and follow this application later with an oil spray on the few resistant varieties. However, to determine the most suitable formulation, one must study the specific plant species to be killed. For example, if a right-of-way consisted mainly of ash, oak and red maple, I would choose oil as the carrier and use a low volume sprayer. Afterward, as often happens, sumac, cherry and birch will start to grow on this right-of-way. Then, if the terrain permitted, I would use a 2,4-D—2,4,5-T water spray. This problem is one of exchanging the undesirable plant species for those which are desirable on power lines, like grasses, the common weeds and ferns and low shrubs such as our native blueberry.

I would like to spend a minute on formulation. The esters of 2,4-D and 2, 4, 5-T are now being used extensively in water and oil formulations. As I pointed out to this Conference last year, one must be careful in using the esters on roadside or power line work because of possible damage to nearby desirable plants from drift and volatility.

Our company and other companies are working with esters of a low order of phytotoxic volatility. When we speak of phytotoxic volatility, we mean the effect on plants caused by the volatility of the ester. I do not have the time to develop this point further except to state that we are now producing esters, such as the butoxy ethanol, having much less phytotoxic volatility, and that the killing power of these new esters certainly is as good as the ethyl, butyl, isopropyl and other esters with which we are now more familiar.

Now let us discuss the possibilities of killing brush in the dormant season. The most succesful approach to this problem is in cutting the brush and spraying the cut stumps with mixtures of 2,4-D and 2, 4, 5-T in oil. The concentration of acid will vary from 1 percent to 3 percent on an acid basis. I believe the key to success with this method lies in covering all sides of the stump thoroughly to the ground level. This method has many advantages over those previously discussed and is not limited to dormant work, but can be used at any time of year after the tree is cut.

Utility men are constantly cutting new right-of-ways, and re-cutting the old ones which have grown too high for economical spraying. Often the terrain does not permit the use of power sprayers. One man with a knapsack sprayer can follow a cutting crew and apply these mixtures to the stumps, thus eliminating as high as 80 percent of the regrowth. Another advantage with this treatment is that all species seem to be susceptible to it. On roadsides this method has merit because it can be used when susceptible crops are not growing. It utilizes man power during the off season, and by cutting, piling, burning and then spraying the stubble, a neat roadside results.

From an experimental standpoint, I believe more work should be done using water and water-oil emulsions with penetrants as the carrier in order to cut down the amount of oil needed.

A rather new method, and one which requires additional research, is the "basal treatment" when the brush is dormant. During the past year we applied over 100 different formulations of 2,4-D and 2,4,5-T with water and with oil as the carrier. Treatments were made using 1 percent, 3 percent and 5 percent of acid in each case, and the material was applied uniformly to the base of woody plants which were 4 to 5 feet tall at the time. This work was done in February and March with the temperature in the low thirties.

We have evaluated these plots several times this summer, and I can assure you our opinion of the various formulations changed at each observation. Our last observation in September of this year showed that the best kill (95 percent) was with the 5 percent acid weight of 2,4,5-T butoxy ethanol ester in oil or in water. This water treatment was a complete surprise to me and we are now running a complete series on water ond water-oil emulsions, starting November 1, 1949. The best result from a low concentration of acid came from our emulsifiable 2,4-D acid—an 86 per cent kill with 1 per cent acid. This compound will be investigated further.

In conclusion, based on our observations under eastern conditions, I believe a 12-month program for the control of brush is possible. Use an overall spray of 2,4-D plus 2,4,5-T in water or oil during the growing period, and during dormancy cut and spray stumps on those parts of the right-of-way or roadside which are either too tall to spray near susceptible crops or are not accessible to mechanical equipment.

Program Discussion on Twelve Month Spray Schedule for Killing Woody Plants

M. W. Day

The use of chemical herbicides, or silvicides, in forestry is limited generally to the following applications: 1. As a means of eliminating a brush cover prior to planting, seeding or the esablishment of natural reproduction. 2. For the release of valuable young growth that is being overtopped by brush or inferior tree species. 3. For the elimination of undesirable trees from a stand of other wise desirable trees.

In the Lake States there are several factors that tend to limit the length of the field season. Weather and road conditions during the winter will usually preclude this type of work. Heavy spring and fall work schedules will usually result in this type of work being done in the summer. Fortunately most experimental work has indicated this to be the best season. This would indicate that at present in forestry a 12 month spray schedule is not usually feasible. However, in certain cases it may be possible to considerably extend the work period through the use of dormant sprays.

The killing of brush prior to planting is an operation, like almost all others in forestry practice, requiring the lowest possible cost inasmuch as all of the plantation establishment costs must be carried for long periods at interest before any returns will

be realized. It is generally felt, I believe, that spraying for this purpose can be done best and cheapest in July and August using a water solution of 2,4-D or 2,4,5-T. The formulation and concentration used will vary with the species being treated, but concentrations of 2000 and 4000 ppm (parts per million) of the esters are usually sufficient. Several of the brush species presenting the greatest problem in planting areas, such as hazel, alder and willow are quite sensitive to 2,4-D and 2,4,5-T. The use of an oil spray applied during the dormant season or while the buds are opening offers some good possibilities. Results with this method have been varying and more work is needed to determine the proper technique. In general the best results have been obtained with 4000 to 8000 ppm of 2,4,5-T ester in oil applied to the twigs and stems during the dormant period. When applied after the buds are swelling, there seems to be considerable resprouting. This method of treatment may prove to be desirable for release purposes as well as for planting site preparation.

Summer foliage sprays appear to be best for the release of desirable young growth from overtopping undesirable species. The overtopping species is usually broadleaved and its foliage protects the favored species, usually coniferous, and thereby decreases the damage to the latter. Some of the coniferous species have shown greater resistance to 2,4-D during the later part of the growing season and therefore late July and August appear to be best for this type of work. Zehngraff obtained the best results in this type of work with 1½ lb. of 2,4-D in 80 gal. of water per acre. Of the conifers, white spruce has shown greater resistance to 2,4-D than white pine. Unlike other control work, this type of treatment does not require a complete kill of the brush and therefore lower concentrations may be used to avoid injury to the desirable species.

The elimination of undesirable trees or species from a stand is often silviculturally desirable and offers the most latitude in time of treatment. It is accomplished by cutting, girdling or poisoning. After cutting it is often desirable to treat the stumps to prevent sprouting. The methods and formulations are similar to those used in right-of-way work. A solution of 4000 ppm of 2,4-D or 2,4,5-T ester in Diesel oil is effective on most species in our region. The newer 2,4,5-T has quite clearly demonstrated its superiority for this treatment. Poisoning of standing trees has been usually done with sodium arsenite or ammate. Experiments with the use of 2,4-D as a poison for standing trees have not been very successful. Injection treatments of aspen with 6000 ppm to 20,000 ppm solutions of both 2,4-D and 2,4,5-T resulted in kills but on red maple the same treatments were successful only with 2,4,5-T. Further work is needed on formulations for this treatment. To date, this treatment has been tried only during the growing season.

Brush Control in Southern Pasture and Range Land

L. L. Coulter

The control of woody plants in pasture and range lands is a problem of vast areas, dealing, in many instances with land of low productivity. Any control program designed for this area must, therefore, be based on an extremely efficient means of controlling brush and encouraging grass. At this point the aerial application of 2,4,5-T—2,4-D mixtures appears to approach the standard of efficiency required for this program.

At Spur, Texas, C. E. Fisher has done some very extensive and carefully planned work on the eradication of mesquite from the range lands of that area. This year airplane applications of 2,4,5-T have given outstanding control of top growth and, as indicated by inspection of the roots and bud zone, have given extremely good control of the entire plant. These tests demonstrate rather clearly the importance of 2,4,5-T or mixtures of 2,4,5-T and 2,4-D. Fisher believes, and his ideas have been verified in other sections of the country, that 2,4,5-T acts more consistantly and is less subject to the influence of environmental conditions than is 2,4-D or the mixtures of the two. It is interesting to note that the aerial applications made during May of this year appear to be more effective than hand applications made at the same time. While apparently satisfactory results have been obtained with as little as 1/3 lb. of 2,4,5-T per acre it is probable that at least 2/3 lb. will prove to be most satisfactory over a wider range of conditions. Best results have been obtained during mid-May or early June.

Many potential grazing areas in the cross-timbered area of Oklahoma are either completely taken over by this relatively useless timber or have been reduced to the category of woodland pastures with a very low grazing capacity. Various agencies particularly the Red Plains Soil Conservation experiment station have studied this problem from the standpoint of brush eradication and its effect on the subsequent growth of grasses and the grazing capacity of the range. Their work which has been carried out primarily by H. E. Elwell, has demonstrated conclusively, that these wooded areas can be restored to the conditions of good pasture.

Extensive field testing this year, particularly by commercial companies, has shown us the possibilities that exist in the way of chemical control of this brush. In several typical areas, the leaves of large oak trees have been completely killed by one application of a commercial mixture of 2,4-D—2,4,5-T (brush killer). Examination the latter part of this year indicates that a very good top kill has been obtained while evaluations of root-kill have to be made next year. In aerial applications of experimental materials made last year at least an 80 per cent kill has been obtained and native grasses are thriving. Big and little bluestem have covered some of the 1948 plots near Bartlesville, Oklahoma and have grown higher than a man's head in many instances.

Our conception of what constitutes satisfactory

control may have to undergo some adjustment for these problems. In the cross-timbered area 80 per cent has been established as a succeessful commercial control. This amount is sufficient to release virtually the entire range for grasses since those trees, not actually killed in an application with this degree of success, frequently only produce a few leaves which do not interfere materialy with grass production. In the mesquite area top kill for a year is worth a great deal in terms of grass development and in the fact that the successful rounding up of livestock can be accomplished whereas this is extremely difficult in areas where a dense cover of mesquite exists. In this instance perhaps some slow regrowth could be tolerated if respraying was not necessary for two or more years. This of course, is a compromise and certainly not the objective of the resarch worker. In the final analysis the test of effectiveness is measured in terms of additional beef produced. These two range problems are in the advanced stage of eperimental development and have come to the point where reasonable suggestions can be made for extensive field trials. We do not have, however, enough information to warrant an unqualified recommendation for indiscriminate spraying of mesquite or brush in the cross-timbers areas. One of the major keys to the success of this problem is the proper method of application. Unquestionably the practical method is by airplane but we should attempt to obtain more information on the effect of droplet size, carrier, altitude, etc. In the cross-timbered area where we are dealing with extremely dense foliage and large trees predominately of oak, the relative merits of two applications applied across each other or applied several weeks apart should be carefully investigated.

I should like to mention here that dormant season applications seem to offer real possibilities for treatment of brush on a small scale with ground equipment. Successful control of oak brush is relatively easily obtained with fuel oil or kerosene containing 8000 ppm. of 2,4,5-T as an ester. This may be applied as a base spray, overall spray or stump treatment. Similar results may be expected on mesquite. Material may be applied with a knapsack sprayer or any other convenient way of obtaining complete coverage or for use in areas where sensitive crops prohibit foliage spraying. This is mentioned primarily for the rancher who may have some unoccupied winter help and a small scale brush problem.

Workers of the Great Plains Field Station at Woodward have developed the idea of controlling sand sagebrush to the point where it is a growing commercial proposition. Their recommendations of ¾ lb. acid equivalent as an ester of 2,4-D has worked very satisfactorily when applied in May using 3 gallons of diesel oil per acre or 4 gals. of water and one of oil. Mr. Savage and his associates who developed this program will undoubtedly cover sage brush in greater detail. This has been an outstanding contribution to the solution of the range vegetation problem.

Some other range vegetation problems which are not as spectacular as those previously mentioned but none-the-less a real problem in some areas are the control of prickly pear cactus and cherokee rose. A great deal of progress has been made in the elimination of prickly pear with sodium tri-chloroacetate. This is primarily a spot treatment requiring careful application and frequently a second treatment. Results this year have been generally good but somewhat erratic.

Progress is being made in Cherokee rose control and it appears to be a practical undertaking in most situations. 2,4,5-T frequently gives a somewhat more rapid kill than 2,4-D but not necessarily a greater amount of root kill. 1¾ lbs. of acid equivalent of 2,4-D, 2,4,5-T or mixtures of each per 100 gallons of spray appears to be a practical rate of application and another treatment on the regrowth should be anticipated.

In developing the chemical control of rangeland brush problems the research worker has provided the rancher with an efficient tool which can become a part of the range management program. It should be emphasized that it is part of a management program including spraying, seeding (in some instances) and judicious grazing. Chemical control is efficient and it provides a maximum amount of litter to check erosion and support grasses. It is, of course, injurious to lespedeza pastures but does not effect grasses. With proper, conervative development, this program can become a success and solid grass lands may once more be established with chemical brush control.

A Twelve Month Spray Schedule for Killing Woody Plants in Northern Pastures and Woodlots

Henry L. Hansen

Unfortunately, from the standpoint of this particular subject which has been assigned to me, the seasonal aspect of the problem of woody plant control has not been tested as thoroughly as have the variations in other factors such as the nature of the spray material and its concentration. With relatively few exceptions, spraying has been done during the growing season.

Quite a long list of species might be considered as troublesome on occasion in northern pastures and woodlots. The following represent the more common species present:

hazel brush—*Corylus cornuta* and *C. americana*

wolfberry or buckrush—*Symphoricarpos occidentalis* and *S. orbiculatus*

prickly ash—*Xanthoxylum americanum*

sumac—*Rhusglabra* and *R. typhina*

rose—*rosa sp.*

alder—*Alnus incana* and *A. rugosa*

willow—*Salix discolor, S. bebbiana, S. nigra, S. amygdoloides*

blackberry—*Rubus allegheniensis*

raspberry—*Rubus occidentalis* and *R. strigosus*

dogwood—*Cornus candidissima, C. stolonifera*

cherry—*Prunus virginiana, P. serotina, P. pennsylvanica*

also some tree species including aspen and various oaks.

It would obviously be impossible to discuss each of these species and stay anywhere within the limits of time imposed on this discussion. I would like, therefore, to cover particularly some of the work which we have done ourselves at the School of Forestry of the University of Minnesota. This work has been primarily concerned with 3 species; hazel brush, wolfberry and prickly ash. These species by virtue both of their common occurrence as pasture weeds and their great tenacity of life and ability to sucker and sprout are probably our most serious northern woody pasture weeds, at least in Minnesota.

In the case of wolfberry and prickly ash we do not feel that we have developed techniques that are successful as practical control measures. As an arbitrary yardstick in determining whether or not a treatment is promising, we have felt that a single application or treatment should kill all or nearly all of the existing stems plus reducing the number of suckers developing subsequent to the treatment to less than half of what would have developed in the absence of the treatment. Any results less effective than that would seem to be rather ineffective even if repeated several years.

Our tests on wolfberry and prickly ash have, of course, covered only a fraction of the full array of possible combinations of chemicals, concentrations, seasons of application and other factors. Excluding all of our tests on which we have less than 2 years of observations as being an inadequate testing period our work has covered the following:

1. The midsummer application of ethyl ester forms of 2,4-D at concentrations of 1,000, 2,000 and 4,000 ppm.

2. The midsummer application of siopropyl ester forms of 2,4-D at concentrations of 1,000, 2,000 and 4,000 ppm.

3. The midsummer application of isopropyl forms of 2,4,5-T at 1,000, 2,000 and 4,000 ppm.

4. The midsummer application of 50-50 mixtures of 2,4-D and 2,4,5-T (isopropyl forms) at 1,000, 2,000 and 4,000 ppm. In these tests at least 3 replicates were made for each treatment. In a few cases the results were reasonably satisfactory on a single plot. However, in no case where all of the plots were averaged together did the results exceed the previously mentioned standard of success. There is definite indication that 2,4,5-T is less successful in the treatment of this species than is 2,4-D.

The results with prickly ash have been pretty much the same—no generally satisfactory treatment. However, this species has been subjected to a wider variety of treatments during the past season and it is hoped that a successful treatment will be found among those used.

Most of our research efforts in the field of chemical sprays have been directed toward hazelbrush control. This species, or rather these 2 species, constitute the most important woody weeds in Minnesota pastures in addition to being a serious obstacle to the practice of good forestry on farm woodlots and other forest areas. Our experience with hazel brush has included the following:

Date	Treatment	Results
I. Aug., 1946	70% sodium salt of 2,4-D using 1.16 lb. acid equivalent per 133 gal. of water per acre (1150 ppm)	(per acre basis) Approximately 14,000 stems of hazel brush before spraying
Aug., 1947	Same as in 1946	(no counts made)
1949	none	approximately 1400 old live stems, approximately 7350 new stems. Total of 8,750 stems or 63% of original number in 1946.
II. Aug., 1946	70% sodium salt of 2,4-D using 1.16 lb. acid equivalent per 133 gal. water per acre as in no. I. (1150 ppm)	14,000 stems of hazel brush before spraying, same area as no. I
Aug., 1947	resprayed using an ester form of 2,4-D	no counts made
1949	none	approximately 140 old stems approximately 3500 new suckers. Total of 3650 or 26 per cent of the original no. stems in 1946.
III. 1948	2,4-D ester form using 1 lb. acid equivalent in 12 gal. water per acre (10,000 ppm.)	17,140 stems of hazel brush per acre before spraying
1949		3,780 old stems still alive 3,500 new stems. Total of 7280 stems or 42 per cent of original no. stems in 1948.
IV. July 24, 1948	3 lb. 2,4-D acid equivalent (ethyl ester) in 50 gal. water per acre. (7500 ppm)	26,000 stems hazel brush per acre before spraying
June 14, 1949		18 stems per acre alive (8 per cent of no. before 1948 spraying) (too early for much suckering)

On the basis of our experience with hazel brush I feel that the following statements could be justified:

1. Complete defoliation of hazel brush plus complete or nearly complete kill of above ground stems is now a relatively easy matter involving the application of proper concentrations of ester forms of 2,4-D or 2,4,5-T acid as a foliage spray.

2. The extent of resprouting and suckering the season following a single spraying can be reduced to a point where the brush population is well below half of the original number of stems. However, a single spray treatment is not adequate in bringing the brush under complete control.

3. Follow up sprayings the second or third season can be used to reduce the brush population to a point where sod competition plus the trampling by grazing animals make it no longer a problem.

4. A series of 3 annual sprayings is probably necessary to render a 100 per cent eradication job.

5. The effect of season or growth stage when spray-

ing is done on effectiveness has not been thoroughly tested. However, there is some indication that the least amount of resprouting occurs from midseason or late season spraying. There is also a possibility that dormant season spraying may be successful.

Informal Remarks Concerning the Progress Made in Research on Eradication of Woody Plants

L. W. Melander

From the dicussions you have heard tonight, you will agree that chemical treatment is rapidly replacing mechanical methods for the destruction of woody plants. This is especially true in territory where it is not necessary to remove the top growth. Thousands of miles of rights-of-ways, thousands of acres of rangeland, and millions of alternate hosts for plant diseases now are being treated with chemicals each year. The use of chemicals in place of mechanical means has materially reduced the cost of eradicating these undesirable woody plants. From the apparent "kills" that have been obtained through the use of chemicals by large-scale operators as well as through field experimentations, it appears safe to predict that within the next few years the killing of woody plants with chemicals will become much more of a general practice.

What has brought about this drastic change, and what must be done to improve and perfect our present methods of woody plant control?

Undesirable woody plants enter into almost every phase of the noxious plant problem. They

1. compete with crop and pasture plants
2. obstruct rights-of-way
3. attack crop plants
4. spread or carry plant diseases
5. are injurious to men and animals

With these different types of undesirable plants and the different locations, the problem varies. There is little doubt but that the use of chemicals will provide the most economical control.

Do we now have an ideal chemical eradicant? Do our present chemical eradicants of woody plants have the desirable attributes of an ideal herbicide?

1. Are they readily absorbed by the plant?
2. Are they selective from the standpoint desired?
3. Are they highly toxic so that only small quantities will eventually kill the plant?
4. Are they sowly toxic so that they will not kil the pant tissue before penetration takes place through most of the tissue systems?
5. Are they harmless to man or animals?
6. Are they harmless to the soil?
7. Are these chemicals cheap and available in large quantities?

Some of the chemicals that we are now using have most of these qualifications except that they do not give the desired degree of "kill." Here an important question arises. In our search for more efficient and economical methods of killing woody plants, are we going to be satisfied with mere *control*, or should we strive for *complete eradication*. We certainly have come a long way, but those who are conducting a search to find more effective chemicals that will kill woody plants should raise their "sights" to the goal of *complete* kill in one treatment. With most species we now have to be satisfied with a high degree of *control* which later involves the problem of re-treatment. Re-treatment to obtain complete eradication is costly. Still, the cost of using chemicals for practical control, including re-treatment, is much more economical than using any other method of eradication. If we should achieve the goal of obtaining chemicals that can be used for special types of plants and effect a complete kill with one treatment, the cost of eradication of woody plants would be reduced to the level of the present cost of mere *control*. It is essential, therefore, to obtain more toxic chemicals and to improve the techniques of applying the chemicals we now have. The latter point might even aid in partially obtaining the objective of *complete eradication* with one treatment, using the chemicals now available.

It appears that within a few years, with the interest shown in research on woody plants, the changes in methods of eradicating these plants cheaply and efficiently will be revolutionized far beyond the scope of our present comprehension.

On behalf of the subcommittee on research of eradicating woody plants, I want to take this occasion to thank all of those who have made contributions of material which made the 1949 report of the subcommittee possible.

After the formal program was completed, opportunity was given the audience for questions. Several questions were answered by various people who had participated in the program.

Meeting adjourned.

Sprayer Equipment for Field Use

W. P. MacDonald

Much has happened since our meeting in Springfield and much more since the meetings at Des Moines or St. Paul. Spraying equipment is coming of age; not perfect, but much better. My comments will deal with ground equipment; more specifically ground spraying equipment. The use of aircraft for weed control will receive full consideration at another session in this conference. Perhaps the other speakers will forgive me for making some references to chemicals and certain other subjects so closely related to sprayers. I hope you will all pardon me for incorporating into my remarks the following letter taken from the files of the magazine, "Commercial West". The article from the magazine is entitled, "Eradicating Weeds By Chemical Sprays", and I quote:

"Editor the Commercial West: According to your request I think I am safe in making the following statements in regard to the future of the work of eradicating weeds by means of chemical sprays in grain and grass fields.

"In 1896 this experiment station conducted a number of original investigations to determine the effect of various types of chemical sprays upon mustard, king head and other weeds which commonly infest grain fields. The work was also applied directly to the cereal grains, and report of the work was made to the Society for the Promotion of Agricultural Science, and a summary of the experiments was given in reports Nos. 10 and 11. Since that date but slight advantage has been taken of these experiments by the farmers in the northwest, while the work of mustard extermination through this means has been pushed quite extensively in foreign countries.

"During the season of 1906 the American Steel & Wire Company of Chicago imported one or more German makes of machines for this field spraying, and had them tried in Wisconsin and at other points, with the result that it has been found that this mode of eradicating mustard is not only an easy one, but that it will be possible for it to be economical. As in other original experiments it is found that grain fields may be sprayed at a rate equivalent to a strip of a rod in width, or possibly more, as fast as a team can walk. The spray practically exterminates all weeds which it thoroughly wets, among these being the worst which the northwestern farmers have to contend with, viz., common mustard (Charlock), and the greater r agweed (king head), annual wild buckwheat, and numerous other weeds go down with the spray as quickly, while the grain has only the tip leaves slightly burned and immediately recovers without any apparent harm or check in its growth.

"Fields which we have experimented upon during this summer stand perfectly clean and free of mustard and king head, while the check areas, at this date untreated, are so overgrown with weeds that it is impossible to see the grain.

"During the present season's demonstrations it has been easy to show that a team and proper sprayer can do from twenty to thirty acres a day, according as the water supply is handy. Our experiments have also demonstrated that while the German type of machine works successfully, that there are many good American traction spray carts which, though much cheaper in construction, are superior in every way to the German machine in the ease with which they can be operated and in the quality of work done. In some cases the nozzles need to be specially adjusted for this field work.

"This department of the North Dakota experiment station is very anxious that this important work should receive proper attention by the farmers of the northwest, but finds the work, as it did at the start, much hampered because of the fact that proper agencies for spraying machinery are not located near enough to the grain fields. Thousands of acres would have been sprayed in the Red River Valley this season had it been possible for the farmers to walk into machine houses and buy a spray cart as they would a plow. I make this statement here that the spray machinery companies may appreciate the matter and establish agencies in a region where there certainly would be great demand for the traction type of machinery. To accomplish the work properly the spraying apparatus should be of the traction type, having strong wheels with wide tires, approximately four inches. It should be compact as a whole, allowing convenience in driving through gates and for storage. The tank should hold at least one hundred gallons of solution. The pump should be in connection with the strong large air reservoir or tank, the reserve air tank being necessary to give constant even pressure. The spray bean should be made in sections so it can be adjusted and thrown up out of the way immediately when the farmer wishes to drive on the road with the machine. There should be approximately eight to ten nozzles equivalent to the Vilmorel type to each rod of spray beam. The pump pressure should be at least one hundred pounds to the square inch. The pump should be of the simplest construction possible. I prefer the simple plunger type, so that in case of trouble a man with a monkey-wrench and a small piece of leather can repair the damage.

"This statement with regard to simplicity applies to the whole machine. The tank should be provided with a large opening or hopper for quick filling, in which hopper there should be at least two fine brass screens to prevent any possibility of clogging the nozzles because of scum or dirt in water.

"For general work of weed killing without injury to the smaller grains, we have found that one hundred pounds of iron sulphate, dissolved in fifty-two gallons of water, and applied evenly to an acre of ground will give splendid results on practically all weeds that it will wet. Fifty to seventy-five pounds will do good work on young mustard. With this solution once over, all mustard and king head of reasonable age will disappear from the grain. The spraying is best done when the grain is 6 to 10 inches high. Canada thistle will be so blighted as not readily to produce seed. This latter plant, however, is quite sturdy and I would recommend spraying once in the morning and then again with the same solution over the same area later in the day, or on the following day.

"We have found for use on king head that common table salt applied at the rate of one-fourth to one-third of a barrel to each fifty-two gallons of water is a marked success. This salt solution is also thoroughly effective in blighting down the Canada thistle, preventing it from blossoming.

"Copper sulphate, used at rate of 13 pounds to each 52 gallons of water, is a good substitute for the iron sulphate.

"Commercial sodium arsenite, a strong poison, has been found the most effective of all weed killers. One to two pounds of this substance to each fifty-two gallons of water, according to the nature of the weed handled, has been found thoroughly effective. It seems to be par excellent against Canada thistle and king head. Sodium arsenite is not yet commonly found upon the market, but we purchased what we used at the rate of ten cents a pound. It may be had of the wholesale trade at from 10 to 15 cents per pound. I predict a great use for this substance, but care should always be exercised in handling it.

"As yet we have not obtained good results in checking the development of the perenial sow thistle.

"——H. L. Bolley, North Dakota Agricultural College, Fargo, July 18, 1907".

I suggest to you that the use of chemical sprays and an understanding of weed spraying equipment appears to have been a lost science from 1907 until about

1939 when the dinitro chemicals came into the picture. Let me recall to your attention one paragraph from Dr. Bolley's 1907 statement: "This statement with regard to simplicity applies to the whole machine. The tank should be provided with a large opening or hopper for quick filling, in which hopper there should be at least two fine brass screens to prevent any possibility of clogging the nozzles because of scum or dirt in the water." Simplicity was and should continue to be the keynote for good sprayer design. He also made a very pertinent reference to adequate strainers. It has taken up quite a few years to satisfy ourselves of the simple truth of these statements made more than 40 years ago. Dr. Bolley, I believe, is still on the staff of the Agricultural College at Fargo. Time has proven him an unusually keen observer and a wise prophet and an early understanding on his part of the essentials for a good weed sprayer was just one of his many accomplishments.

At this same meeting last year it was stated that the chemists and other research workers employed by manufacturers and formulators of 2,4-D also had a responsibility in insuring the satisfactory operation of sprayers. Everyone wanted a chemical which was satisfactory for use with the waters available for dilution. Probably the biggest single improvement made in sprayers during the past year was achieved in the chemical laboratories. The point is that the farmer is the ultimate judge of the performance of a sprayer and if, as happened in 1948, he was plagued with clogged nozzles, booms and even tanks, he was likely to turn his wrath on the builder of the machine. Fortunately for those of us who distribute sprayers, the chemists came up with the answer to the problem of precipitates which resulted from the use of hard water. The happy consequence of this achievement has been that many operators who were determined that their 1948 sprayer had the wrong kind of nozzles or boom, or insufficient screening in the line, used the same machine without alteration with the new formulations in 1949 and were completely satisfied with its performance. We salute the chemical companies on their accomplishment, for as far as 2, 4-D is concerned, they have greatly simplified the problem of the sprayer manufacturer.

The time is certainly here when we should discontinue calling these machines weed sprayers. They are proving useful on the farm in many ways in addition to the control of weeds. Possibly in this very area next year, as many sprayers will be sold for the control of corn borers and grasshoppers as for the contol of weeds. I suggest that in this connection there is still a great need for the chemists to collaborate with the metallurgists and the sprayer manufacturer. Chlordane reportedly is damaging to galvanized iron and TCA in concentrated solutions is highly corrosive to aluminum. These are two popular materials for the construction of sprayers and if their use is to be restricted other materials less satisfactory in certain respects will have to be substituted. Doubtless in the impressive list of agricultural chemicals intended for use by the consumer as sprays there are other materials equally detrimental to certain metals. When a new agricultural chemical has been released in recent years it has been common practice to indicate whether or not it is compatible with certain other chemicals. For example, the manufacturers were quick to point out that chlordane and toxaphene might be mixed with 2,4-D in order that the control of certain weeds and insects might be effected with one spraying operation. It would certainly be worthwhile for the producers of new chemicals to immediately institute research for the purpose of determining the effect of the product on the materials that go into the construction of spraying equipment. Of course, this is an added complication in product research, but if it is not made in the laboratory, it will have to be made in the field and while the practical field experience is being gained, sales of the new product will suffer.

Last year we were quite critical of equipment on two counts—these were nozzles and pumps. The improvemnet in nozzles has been significant and praiseworthy. It is true that some recent experimental evidence indicates that even with the best available nozzles the coverage leaves something to be desired. Nevertheless, the final proof would seem to rest in consumer acceptance, and using that yardstick, most of the low volume nozzles currently being offered are very satisfactory. During the season just past, we have not observed any cases of poor coverage in the field due to inferior spray patterns. It is not likely that a nozzle and boom combination will ever be developed which will always give a perfect pattern under actual operating conditions. It should not be impossible to develop and space nozzles so that they will produce an absolutely uniform coverage under laboratory conditions, but in the field there must be some overlap of patterns to insure complete coverage. A careful operator may very accurately calibrate his sprayer to apply, for example, 4 ounces of 2,4-D acid equivalent with a known quantity of water per acre. In actual practice, however, if the boom has a vertical movement of 6 or 8 inches on rough ground, some of the plants are certain to have double coverage. Also, there is a considerable variation in the height of plants to be sprayed, even in fields that we think of as being uniform. Therefore, with the theoretically perfect nozzles, under field conditions you must expect some double coverage in order to be sure of getting single coverage of all plants. The use of caster, or support wheels of some kind, on the booms of many of the new sprayers has done much to increase the uniformity of application. In connection with nozzle patterns, the University of Wisconsin College of Engineering recently announced the development of a device for accurately determining delivery. This machine, known as the Pulse Length Sorter and Counter, reportedly employs an electronic principal to rapidly sort and count the droplets from any nozzle. Perhaps it will prove of value to nozzle manufacturers. However, to repeat, it is my opinion that while the newer nozzles may not be perfect, they represent a big improvement in performance and appear to be doing a most satisfactory job.

Pumps have also been improved but much more research and development is needed to bring them up to the standards of performance set by nozzles. The biggest improvements have been made in better methods of applying and retaining lubricants and in increasing their useful life. Possibly more sprayers use gear pumps than any other type, but good results are

also being obtained with various others such as rubber impellers, rollers, centrifugals and pistons. Pumps big enough to do the spraying jobs are sometimes too small to satisfy the user when it comes to filling the tank. The speed of fill against no pressure is being boosted in some instances by the use of jet devices. It has been encouraging to note that in the last year at least two pumps were offered which embodied some radical changes in design. The ones that come to mind did not produce startling improvements in performance in the field, but they do establish that pump manufacturers are willing to depart from the conventional in an effort to develop better units. The ultimate objective should be to get a pump with a wide pressure range, probably up to about 150 pounds per square inch, a low power requirement, adequate delivery, low initial cost, and long life under the conditions that prevail for farm spraying. That is quite a big order, but we are certainly moving in the right direction.

According to the information that we have been able to obtain, the 1949 model sprayer stood up well under ordinary field usage. Frames were stronger than previously and booms were more rigid and better braced. It does seem to be a fact that the average farmer appreciates that when spraying with either tractor mounted or trailer type sprayers, he is handling a very light load for his tractor. He therefore is inclined to operate at higher speeds than he would employ if engaged in some operation requiring a greater part of the available power. It appears necessary to build sprayers to withstand the abuses of more speed in the field than is required of other implements.

When we confine our thoughts to 2,4-D, and assume that the spray line and nozzles are adequately filtered, which is true of practically all of the machines currently being offered, nearly any kind of material or combinations of several kinds can be used in tanks, pumps and booms. Even black iron booms have performed very well with good screening and a formulation that does not react with hard water. As was mentioned previously, certain other chemicals do react to some materials and this must be borne in mind if the machine is to be used for purposes other than weed spraying with 2,4-D.

With complete sprayer units having their own power as well as with some tractor mounts, there has been a tendency to develop line leaks due to the vibration encountered. This has been largely done away with through better bracing and the substitution of hoses and metal tubing or pipes. When rubber or synthetic hoses are used they must be of such composition as to resist the herbicide and insecticide formulations as well as do the metals.

The type of sprayer that is to be used can be determined only by the wishes of the purchaser. Both the mounted and trailer types offer advantages and some drawbacks. Certainly with other things being equal, the mounted type machine must be easy to attach and dismount. Lacking convenience in this respect, it will probably be used only once during the season. With the trailer type, there must be above the ground clearance equal to that found on row-crop tractors or it can not be used for insect control in inter-tilled crops. Both types must be provided with controls readily operated from the tractor seat and the pressure gauge must also be readable from that point. From the standpoint of economy and the importance of putting the spray only where it will be beneficial, it is important that some arrangement be incorporated into the design which will permit an immediate shutoff of spray at the election of the operator. This generally has been accomplished in two ways—that is, either by employing check valves in the individual nozzles, or by a valve arrangement which will permit a reversal of the direction of flow of the chemical. A means of agitating the solution in the tank when mixing is essential and it is also quite desirable to have some degree of agitation in the tank while spraying. Mechanical agitation devices are quite expensive and a simple bypass from the pump back into the tank has generally proved sufficient. Many sprayers are now equipped with hinges or swing joints on the boom which will prevent damage should the boom strike an obstacle. These joints serve a purpose and have generally appealed to the prospective buyer. When they are built into a machine they must be well engineered for if they are not absolutely rigid in normal operation, movement forward and back will produce uneven coverage and add one more complication to attaining a uniform spray pattern. Some kind of a break joint which will prevent damage, even though the boom must be returned to proper position by the operator, is probably the acceptable minimum along this line. Most spraying is done in open fields and only on the first and last rounds must the operator be careful about striking obstacles.

There is no particular point in going into detail on volumes of solution per acre for weed work. Most machines are designed to apply in the neighborhood of 5 gallons per acre; some can be changed from as little as one or two gallons per acre to more than twenty gallons by a choice of nozzles, operating speeds and pressure. Some work at the Idaho Experiment Station indicates that extremely low volumes may result in increased crop injury, but this damage may not be as important as the savings in time and water effected with low volumes. Aircraft have generally been successful with volumes considerably below that commonly used by ground sprayers and perhaps further serious consideration should be given to much lower quantities of solution. In one series of tests in Canada during the past season the results indicated that one or two gallons of water were equally as effective as a like quantity of oil when combined with 2,4-D for weed spraying. Our own tests in 1947 showed that with volumes of solution as low as two and one-half gallons per acre, weed control was as good and crop injury no greater than when higher volumes were applied.

For raodside spraying, any type of boom which extends beyond the edge of the road presents some problems. Even those which are hydraulically or mechanically manipulated from the tractor seat must be lifted out of the way when passing mail boxes or other obstacles. This not only is bothersome to the operator, but will generally result in skips. In this connection the University of Manitoba has released a leaflet which shows how to build a sprayer using only three nozzles on a vertical boom and claimed to produce a satisfactorily uniform coverage for dist-

ances up to 28 feet with 150 pounds pressure per square inch at a six-gallon per acre rate. Doubtless the coverage would be influence by wind velocities when spraying. It is indicated that this machine was designed for use with insecticides rather than with herbicides where the uniformity of coverage is considered more important. Anyway, it raises some interesting possibilities for design of sprayers for roadside use. A spray gun and nozzle employing somewhat the same principal is currently being manufactured in Wisconsin.

Some mention must be made in connection with the use of sprayers for corn borer control. The State of Iowa doubtless sustained losses from this pest in 1949 equal to or exceeding those of any other state. While not by any means discounting the value of cultural practices to control the borer, we understand that the Entomology Department in Iowa feels that chemical methods offer by far the best immediate opportunity for control. Most investigators seem to be of the opinion that for spraying with DDT, ten gallons of solution per acre gives better control than lesser volumes. It also is generally agreed that it is desirable to apply the materials from above the plants to wet the upper leaf surface and particularly to get some of the insecticide into the leaf whorls. This result is best accomplished by the use of three nozzles, each delivering about one-third of the spray. One nozzle should pass directly over the row with the other two angling in from the side. Corn borer control represents an important field for the use of sprayers, and manufacturers will want to keep this in mind when designing future machines. From results obtained last season it would seem that the ordinary weed spray without modification is suitable for the application of insecticides for the control of grasshoppers and certain other insects.

To summarize, it is correct to say that sprayers have shown much improvement in the last year. Nozzles, tanks and booms on most machines are quite satisfactory. Further improvements and design in pumps might be desirable. At this time the prospective sprayer purchaser can be reasonably sure of getting about what he pays for in a machine. Whether he wishes to pay $150, or ten times that amount will depend on the use to which the machine will be put, the acreage to be treated and the expected useful life of the equipment. We can truthfully say that farm sprayers are coming of age.

The Role of Education in the Weed Control Program

U. J. Norgaard

Probably no subject is more misunderstood than the role of education in public programs—in spite of much effort which has been made to make us understand just what it is and what it is not—whole libraries have been written about it.

One pessimist has said that the greatest wonder in the world is the resistance of the human mind to education.

Other gloomy commentators have stated that education as such is always a dull subject to discuss.

I am happy to state that all of these gloomy friends are mistaken because—Education is the most interesting of all subjects to study! Especially when the subject is weed education.

There are hundreds of definitions of Education and it is necessary to try to define it if we are going to apply it to our great weed control program.

To save time, I have selected the shortest definition I could find. Education, according to this authority, is "a change, in knowledge, skills and attitudes."

Now how can anyone say that Education is a dull subject? Think of it. If true, then all progress depends upon education. We cannot and do not advance faster than the educational program permits—because intelligent action awaits upon the will of people who have changed in knowledges, skills and attitudes.

There is another point on which all authorities agree—Motivation for action must come from within. Otherwise no permanent change has taken place. Permanent change will come only through understanding.

Here is where we often get into trouble because our public programs are sometimes dominated by people who do not understand this principle. Unfortunately it is possible to influence people temporariily by numerous other devices.

Temporary compliance to a program activated by motivation that comes from without does not mean that education has taken place. There is much temporary compliance of this sort parading as the real thing.

Yes, we have many kinds of people who influence Public Programs.

We have enemies of Education—like the Dictators who would use coercion or compulsion to achieve their goals. They are the ones who always say "We ought to have a law". They talk about "program by directives". They are the people who are causing so much trouble in both large and small programs. All over the world. A great self respecting farm people do not want a compulsory program by a dictator.

Then we have the "lukewarm" folks, who may say they believe in education—but, when it comes right down to business, they are unwilling to provide for finances for personnel and facilities for an adequate program. We often hear "lukewarmers" apologize for the slow motion which they call a "practical" program. They say: "well, let's do the best we can, (under the circumstances)", "We will not get far in our time." "People aren't ready"—perhaps— "If we sow a little seed"—"The next generation will control the weeds".—So it goes from generation to generation. These folks who live this philosophy do not know the power of education!

Then we have another group—don't know just what to call them. They are impatient, restless—perhaps the modern title "Eager Beavers" may fit. They want something done this year, this month, this day—right now! They don't even think about the next generation.

They do not know that motivation must come from within as a result of education. Sincerely they be-

lieve that the quickest way to influence people is to activate them from without. "Let's mow them down!" is their slogan. Education is not their field. I think they would be insulted if called "teachers".

How shall we describe their activities?

Perhaps,—in a weed conference it would be appropriate to refer to their activities as weeds in the educational field.

For instance, we have the weed in our educational field called the 'urger'.

So and So ("great man") urges farmers to kill their weeds! What a noble statement. The urger is just the opposite of the educator. The urger tries to influence people from without. The educator never urges. This harmful word gets into publicity headlines. I suppose it is because it is a handy word that just fits headlines. If I were an urger I would urge headline writers to throw that word right out of the window! It does untold harm and has just the opposite effect as intended.

Another noxious weed in our educational field is the 'contest', when used in an attempt to activate people in a program. The sponsors of contests do not believe that their programs are of sufficient interest in themselves—we must appeal they say, to the competitive instinct.

We must line people up and say— "you are in a contest",—now go out and beat somebody. I would'nt be a bit surprised if someone some day would start a prize contest something like this:

All you have to do is to finish this sentence: "I should eradicate noxious weeds because————."

I am not belittling contests and competition as such, —like in games or pie eating contests and the like. They are contests for contest sake. They are an indispensible part of human enjoyments. But in the educational field contests are obnoxious, to say the least. Many have classed contests as one of the lowest forms of education. I think they are right.

Another noxious weed in our educational field is the 'mobilizer'. 'Mobilizers' assume the role of organization experts. They are just the opposite. They use only organizations built for other purposes. When they get the urge to launch their program—they go to the directory and get a list of all existing organizations who they intend to mobilize for action. None are left out!

These mobilized program all die aborning. They are detrimental because they consume time, cost money and distract and dissipate our energies.

Certain short time campaigns for general welfare or patriotic objectives may be handled through the mobilization method—but not a weed control program, because by its very nature, it requires a different treatment.

We must not forget the formidable noxious weed called "Bally hoodeae vociferous." They are the campaigners. They "declare war" on weeds every once in a while. They couldn't think of such a thing as a sustained program. In fact the word program is not in their vocabulary.

They like such devices as "bread eating weeds"— "necktie cleaning week" and the like. They say we must use such devices to make people "conscious" of a problem. They can't conceive of a quiet, sensible, sustained and dignified educational and operational program.

What are the fruits of all these outside pressure schemes? Answer: Mistrust, Resentment, Confusion, Rebellion. Their objective of quick action is good. The pity is that they do not realize that education and organization is the fast and permanent way.

Our goal is weed control in our generation. It can be achieved through teamwork in Research — Education — Organization — Regulation. Weed Control can be made popular if the educational link in the chain is strengthened.

We must be sure to recognize the different phases of education—and we come back to our original definition about *"a change* in knowledge, skills, and attitudes".

In our weed control program we are concerned with all three. Take, for instance, the attitude toward weed control.

We need a "change" in our old concept that weed control is a problem only for the individual. We must —through education—establish the fact that weed control in our modern complex economy is a neighborhood, a community, a county, a state, a national, yes, an International problem.

Such as these are revolutionary ideas. This phase in education is so difficult that we must use the influence of the educator. No other medium or device will suffice. Contact must be man to man.

We must explain and explain and explain:

Why we have the weeds.
Why we let weeds grow, increase and spread.
Why it costs more to keep weeds than to control them.
Why we have the human problems.
Why weed control is a public problem.
Why in a democracy we must have a program built on the principle of voluntary participation.
Why such voluntary program must be backed up by compulsory or regulatory arm to help the few (usually less than 5%) who choose to be forced into doing the right thing for himself and his neighbors.
Why all land, private and public must be enrolled.
Why we must have organization and operational personnel.
Why we need research.
Why the neighborhood unit is the most powerful device to achieve compliance in an organized program. (And so on).

Such work will prepare the field for a successful organized program.

Then as a result of such preparation interest is aroused. The great majority has been motivated from within.

Immediately there is demand for another phase of the educational program—the "how" phase, the knowledge and skill.

How shall we organize?
How shall we regulate?
Help us to identify our weeds.
How shall we make the weed survey?
How can I eradicate this leafy spurge?
Will 2,4-D kill this weed?

How shall I clean my seed?
Where can I get certified seed?
What's the best nozzle?
What about airplane spraying? (And so on).

Who are the educators? Yes, there are specialists in this field who will lead the way. But once the educational forces are set in motion—there is chain reaction and everybody plays the role of educators. There will be meetings, schools, clinics and good publicity about the program in newspapers, magazines, and on the radio. People will inform each other about the facts wherever they meet. There will, as a result, be thousands of demonstrations that speak louder than words.

It is a great satisfaction to see how interested the people are in this all out program and how determined they are to see it through.

If we all help with research, organization and regulation—and with a genuine old fashioned educational program we will make progress—and the noxious weeds will be controlled in our generation.

Truly, there is power in education.

The Problems of Weed Control Officials

Clyde Spry

I could say control versus education and research or which comes first, the hen or the egg.

I shall not attempt to prove that one denotes evil and the other good, or that the first is all sufficient and the other unnecessary.

To regulate or control means "to dispose, order, or govern by rule or system", and to cooperate means "to operate together for a common object". Certainly both of these are necessary in a well ordered society. It is only when they get out of balance that we need to remind ourselves that operating together for a common object is the surest way to guarantee a minimum of control and avoid the next fatal step—regimentation.

A law to be effective must be backed by enforcement. This requires men who are fearless and not afraid to act if necessary. It also requires men reasonably well trained in weed and seed identification. A good program requires that a weed survey be made and this cannot be done by incompetent help. It requires tact and diplomacy.

A good law should be broad enough to include all the noxious weeds that may prove to be a menace. In general the law must be inclusive but not burdened with unnecessary details.

Too many of the leaders in agricultural education and research have drifted along under the impression that our so-called good, ordinary, farming practices were controlling weeds. No one realizes more than we who work on the control program the need for more research and education in how to do the job which we finally carry down to the land owners and occupiers.

Hindrances in carrying out the program seem to be lack of adequate finances, limited and inadequately equipped and trained workers together with administrative and statutory impediments and lack of vision. You must realize that it is the control group that carries on the fight for funds for research, education and control and legislation in order to carry out a more efficient program of weed control. Therefore, research, education and the distributors of chemicals and weed spraying equipment are dependent upon the control program.

Weed regulatory work has two principal parts: PREVENTION, mainly through seed control and other effective means; CURE, through control and eradication methods by proper tillage and use of chemicals and other materials. Each of these parts has three main phases; *research* the basis of all adequate and dependable control; *education* to enlighten the public as to losses from weeds, necessity for adequate control and how it may be accomplished effectively and economically—this duty rests squarely on our educational agencies, the schools and extension services. The third phase is *law enforcement* which is clearly the duty of regulatory agencies.

These problems are principally set forth by legislative action. The legislative body enacts the law. Those employed to have charge of such laws are bound by the provisions of such legislation. If laws on our statutes were carried out, I am sure the weed menace would be much less.

Those of us employed by state governments to have charge of noxious weed laws are charged with the responsibility of carrying out the provisions as well as the spirit and the intent of such law.

Up to 1945 weed research lagged far behind in most states and still does in some states. Some states did little or no weed research work and many states are doing very little or no regulatory weed work outside of the seed law.

Only a few states have an educational or extension weed specialist as have Iowa, Indiana, Nebraska and South Dakota.

There should be a closer relationship in the states between the research and regulatory workers.

Research findings have little value if there is no agency with a program to put the worthwhile results into action.

It is my opinion that the problem of disseminating information dealing with handling the easy-to-kill weeds should be the duty of the extension service and other educational groups as no legal problems are involved.

The information dealing with the problem of the noxious weeds should be handled by the regulatory group as they involve the matter of legal procedure.

Out of this conference will come plans for a better division of the duties of weed control, a better understanding of the efforts put forth by research, educational and law enforcement agencies, and a speeding up and intensifying of research and education where these are lagging behind public and regulatory needs.

Research and education, because of the wisdom and foresight of their founders and directors, from tradition, experience, favorable public sentiment, administrative insistance and consent, and even legal requirements, and protection from political influence have largely enjoyed the benefit of the services of highly trained workers who were selected on the basis of their ability and were protected against political and other disturbing influences.

Regulatory agencies stand closer to and are subject to the shifting forces of changes in government. They are subject to the scrutiny and critical eye of research and educational workers with whome they must cooperate. If regulatory workers do not measure up to the high educational, scientific, technical, and general ability standards expected of them, we must remember that they are as good as legislation, administrative policy, and financial limitations permit or require.

Observations during the past two years indicate that the amount of 2,4-D acid in ester type weed killers should be standardized. Ester type weed killers now on the market contain such a varied amount of actual 2,4-D acid that they are confusing to the dealer and the consumer. A standard acid content will result in a reduced cost to the manufacturers and that in turn could be passed on to the consumer. All 2,4-D should be labelled so that the user could determine from the label the number of pounds or ounces of the acid in the particular quantity that he uses for mixing purposes.

The suggestion is, that the conference make specific recommendations for the manufacturers to follow as to the amount of 2,4-D acid that should be put out by the manufacturers in the Amine and Ester formulations. Making specific recommendations would eliminate a great deal of confusion in the farmers minds and eliminate chances of damage. If he buys one formulation today and another formulation tomorrow it will lead to trouble.

Together, by research, education and control we should be able to plan, motivate and guide weed control along a common battlefront, with intensity and methods fitted to our special needs against our common enemy—weeds.

Response of Corn and Sorghums to 2,4-D and Other Herbicides

O. C. Lee

This has become a habit. Here I am on the program of third consecutive conference talking about the same subject: The Response of Corn and Sorghums to 2,4-D and other Herbicides. Last year the subject for discussion did not include "other herbicides." I am not so sure it should have been included this time. But since it is included, we can dispose of that part very quickly by saying: 2,4-D is the only material that merits the distinction of being classed as a selective herbicide for use in corn. Several other materials have been tried, but as far as I know they have not shown much promise. There were those who at one time thought that 2,4,5-T would have a place for the control of corn field weeds that are somewhat tolerant to 2,4-D as wild cucumber, milkweed, spurges and nightshades. It apparently does not do the job on these weeds, and corn is subject to injury from 2,4,5-T. The injury occurs as leaf burn as the material is somewhat toxic to plant tissues.

For the remainder of this discussion let's talk about 2,4-D. What were the observations and results of experiments made in 1949? The experiment stations of Illinois, Iowa, Ohio and Wisconsin conducted experiments and reported their findings. It is on this work and that done at our own station, Purdue University, that I am reporting. In addition to experimental work, observations were made on 12 demonstration fields and on 84 farms where 2,4-D was used in corn. First let me mention the weather conditions that may influence the tolerance of corn to 2,4-D. Generally throughout Indiana there was an abundance of rainfall following planting. In the area whereon experiments were located it was too wet for best corn growth. Temperatures were below normal. As temperatures increased the later half of June, growth conditions were more favorable for corn growth. I am not sure just what the conditions were in the other states.

Reports as a whole indicate that corn was least tolerant to 2,4-D when sprayed at heights from 10 to 36 inches. Spraying at tassling or just before tassling reduced seed set. Least damage or injury occurred when corn 2 to 4 inches in height was sprayed. Tolerance or damage, whichever the case may be, is determined by degree of brittleness, lodging, curvature of stalk and development of abnormal brace roots. Generally yields were not reduced even though symptoms of injury were noted. Yields were reduced in cases where stands were reduced by breakage of plants following spraying. In other words corn apparently has the ability to recover from the temporary set-back or shock caused by the application of 2,4-D. The degree of injury will vary with the dosage applied. The heavier the rate the more injury occurred providing that growing conditions were the same at the time of spraying. Reports indicate that the amine salts produced slightly less damage than ester formulations when applied at equal rate of acid per acre.

We in Indiana checked the tolerance of our most popular inbreds to 2,4-D. There is considerable difference in their tolerance. It can be said that the reactions of inbred parents is generally reflected in its hybrids, however hybrids appeared to be more sensitive to 2,4-D than inbreds. This could be due to increased growth rate of hybrids or hybrid vigor.

Some of the workers reported their results with respraying of corn. Either two post-emergence or one pre- and one post-emergent applications. Apparently two treatments did not cause more injury than one. In other words the effects of 2,4-D on corn is not accumulative.

All reports brought out the fact that cultivation is needed under ordinary field conditions. It is necessary for the control of grassy weeds. Whether or not more than one cultivation is needed is not too clear. This will no doubt vary with soil type as well as the weed population.

Now that we have three years of research and observation relative to the use of 2,4-D in corn we should be able to draw some definite conclusions. On these conclusions we at least suggest practices and mage recommendations for its use in the future. All of the information gathered points to the fact that 2,4-D can be used as a selective herbicide in corn fields. Its use is recommended only when weeds can not adequately be controlled by cultivation. Spray-

ing with proper dosages of 2,4-D under scuch conditions usually will pay dividends in increased yields. There are several fields in Indiana, and I presume this is true of other states, where corn cannot be grown profitably were it not for 2,4-D. Without sprayiing, the weeds, cocklebur, horse weeds, smart weeds, perennial morning glory and wild sweet potato, prevent the profitable growing of corn.

The amount of spraying that will be done for weed control in corn will no doubt vary from year to year. During wet years when weeds usually are most prevalent and when timely cultivations are difficult to make, many farmers will resort to the sprayer. On the other hand during dry seasons they will rely upon cultivation to control the weeds.

There is one other thought that is worth promoting, and I certainly would call to the attention of farmers; that is the fact that clean corn fields will mean cleaner fields for crops to follow. Since at present we have very little to offer for the control of weeds in soybean, tomato and legume fields, corn may be used to advantage as the cleansing crop in the rotation. We in Indiana already can see the effects of spraying to control weeds in corn. It may not be possible to eradicate or clean up all the weeds, but farmers who have been spraying for the past three years are having less trouble with weeds than before the merits of 2,4-D were discovered. Then also there are farms which have an exceptionally weedy field. I doubt if it would be far wrong to suggest that it be planted to corn so that it can be sprayed, even if it might break up the planned crop rotation for the present.

When recommending spraying with 2,4-D for the control of weeds in corn here are some of the factors to consider—at least as I see them.

1. The practice of spraying with 2,4-D for the control of weeds in corn is recommended in fields where weeds cannot be controlled by ordinary cultivation. Under most conditions it should not be relied upon to replace cultivation but may be used in conjunction therewith.

2. Some injury to corn regardless of dosage should be expected. Lodging, brittleness, curvature of stalks and malformation of brace roots are the symptoms. Such symptoms of injury may or may not effect yields. Reduction in yields are usually caused by reduced stands due to breakage of stalks during the period of brittleness following spraying, and in harvest. The degree of injury is increased as dosage of 2,4-D is increased. One-half pound of 2,4-D acid per acre should be considered the maximum dosage. -Sodium and amine salts usually cause less injury to corn than the ester type when applied at equal rates.

3. Differences in tolerance of strains and varieties of corn to 2,4-D should be recognized. When spraying corn, especially inbred or seed fields, of unknown or low tolerance, dosages of 2,4-D should be reduced to the minimum required to control weeds.

4. Time of applications should be timed to most effectively control weeds. When large corn is sprayed the use of "drops" or nozzle extensions will reduce danger of injury. Small corn appears to be more tolerant to 2,4-D than corn 10 to 36 inches in height, at least less subject to breakage of stalks following spraying. Moisture conditions and temperature favorable for corn growth are conducive to injury.

Now a word about sorghums. My experience with spraying sorghums stands at zero. Mr. Elder of Oklahoma came to my rescue and submitted a fine report as follows:

It is apparent from all reports that sorghum varieties and strains vary in their susceptibility to 2,4-D. Some varieties are able to withstand heavy dosages with little or no injury, while a few varieties are injured by light applications of ¼ pound per acre. As a whole, forage varieties seemed to be more resistant than the grain sorghums.

All investigators observed enlarged or deformed brace roots on treated plots, and when the injury was severe the permanent roots were affected. However, it appears there is less bending and lodging in sorghums than corn. Root damage was not always reflected in the grain yields.

Amine and ester rormulations were used in the tests and the abstracts are not in complete agreement on their effects. One investigator finds no difference in reaction from the two formulations, another reports greater injury to plants when esters are used.

Small sorghum plants, up to 4 inches high, appear to be more susceptible to 2,4-D than larger plants when grain yields are considered. Greater root damage was noticeable on plants 10 to 20 inches high when treated. Evidently young plants are either killed outright or have the ability to recover. Treating during the heading stages of growth did not lower yields at the ½ pound or lower rates. Heavy applications brought on injury which delayed maturity and reduced grain yields.

Summary. From the submitted abstracts it is apparent that ½ pound per acre of 2,4-D can be used on most varieties of sorghums without reduction of grain yields. Heavier rates may cause severe damage in all varieties. A few varieties may be affected by ¼ pound per acre rates. Considerable root deformity may be noticeable without grain or forage yield reduction. Plants under 4 inches high seem to be the most susceptible to injury.

For a final statement I would like to say this: most of you here, whether you are connected with a company or an educational institution, will no doubt have a part in the educational program to bring about adopted practices. Since there are some differences of opinion as to the best method and uses of 2,4-D in corn and sorghum crops, recommendations for the various states will vary. Conditions are sufficiently different so that one over-all recommendation for the entire north central area cannot be made. Therefore, the state experiment station should be consulted for state recommendations. Speaking of Indiana, we have so far merely attempted to guide the program. Now we are ready to fit the practice of spraying corn into our farming system to obtain the best over-all results in years to come. It is a good weapon against weeds in corn and spraying should become a standard farm practice.

Effects of 2,4-D on Spring Planted Small Grains

P. J. Olson

SPRING PLANTED WHEAT, OATS AND BARLEY

Investigations under this head included studies of the effect of 2,4-D at different stages of growth, comparison of different formulations, different rates of application, and differential response of varieties to treatment. Effects on yield, morphologic features and quality were studied.

A. *Effect of treatment at different stages of growth.*

Olson, Breakey and Brown in Manitoba applied ester at 8 to 12 oz. acid per acre to wheat and barley at twenty stages of growth starting before emergence of the crop and continuing at approximately 3 day intervals until after heading. In both crops there were two rather widely separated periods during which severe damage was done as measured by yields that were sharply reduced as compared with the immediately preceding and immediately following treatments. The first was an early period when the plants ranged from¾ inch to 5 inches tall. The second was a much later period shortly before heading in barley and about 11 or 12 days before heading in wheat. These results were obtained at three widely separated stations in Manitoba and were in good agreement with each other.

At Scott, Saskatchewan, Friesen obtained results with wheat, oats and barley, where he applied ester, amine and sodium salt at 15 stages, that were similar in pattern to the Manitoba results except that the later period damage to wheat occurred at stages nearer heading. The results with oats resembled those with wheat and barley as far as the most severe damage was concerned but differed in that here some damage was done at the stages between the two critical periods as well. Little damage was done by sodium salt.

At Lethbridge, Alberta, Sexsmith treated spring wheat and barley with amine and ester at five stages of growth and noted that floret sterility was greatest in the shot blade stage in the case of wheat and the boot stage in the case of barley. Significant yield reductions also occurred as a result of treatment at these stages. This seems to agree fairly well with the Manitoba results for these crops.

Davidson at Indian Head, Saskatchewan, treated oats at 3 stages, namely 3 leaf, early shot blade and early heading. The greatest damage took place at the three leaf stage. At the other stages damage was slight or doubtful. The maximum rate of application was 8 ounces per acre. Ester did the greatest damage and Sodium salt the least. Godbout in Quebec also applied ester and amine to oats at three growth stages, namely 3 leaf, 5 leaf, and shot blade. The rates of application were 2, 4 and 8 ounces per acre. The results agree with those of Davidson just described, in that greater damage was done at the 3 leaf than the shot blade stage. Ester again did greater damage than amine.

Amine and ester applied by Shaw and Willard to Clinton oats at 8 stages beginning at the 2 leaf and continuing to late milk at ¼, ½, 1, 2 and 4 pounds acid per acre. They reported the greatest injury at the 2 leaf stage when highly significant injury was caused by all rates abive ¼ pound. Apart from this stage the ¼ and ½ pound rates produced only slight injury at any stage. The least injury was caused at the 4 leaf and early milk stages. Ester caused greater damage than amine at corresponding rates.

Slife and Fuelleman in Illinois treated oats when they were fully tillered, but had not begun to joint, with ester at rates of ¼, ½ and¾ pound acid per acre. Sharp yield reduction took place at the ½ and ¾ pound rates.

Amine and ester were applied at varying rates from 2 ounces to 1 pound acid per acre by Shafer in Nebraska, to Nemaha oats at 4 stages of growth, namely jointing, early boot, late boot and flowering. When applied at the jointing stage ester, at all rates above ¼ pound reduced yields significantly. At the other three stages no significant damage was suffered.

Carder at Beaverlodge, Alberta, applied ester 2, 4, 6, 8, 12 and 16 oz. to Saunders wheat at the early shot blade stage. All rates above 2 ounces reduced yields. Those, above 4 ounces caused severe reductions. This again agrees with the Manitoba results for this crop.

Taylor at Agassiz, British Columbia, treated oats with ester at 2, 4, 6, and 8 ounces acid per acre. The oats had been sown to red clover. The treatment was made when the oats crop was 10 to 11 inches tall. No significant yield reduction in the oats took place.

B. *Differential response of varieties to 2,4-D.*

Fourteen varieties of wheat, 13 of barley and 16 of oats were involved in the investigations reported. Seven stations are represented. Davidson in Saskatchewan compared Ajax, Vanguard, Fortune and Exeter. Olson and Breakey in Manitoba compared Ajax, Vanguard and Exeter. In both cases Ajax was found somewhat more susceptible to damage and Exeter the least. Ajax is early and Exeter late. Vanguard was a close second to Ajax in damage suffered in Manitoba. Ajax showed slightly greater reduction in yield than Erban in a comparison by Godbout in Quebec. Shaw and Willard, in Ohio, compared Columbia, Ajax and Mindo. These are named in the order of injury from the least to the greatest. The authors point out that these varieties did not rank in the same order under similar treatment applied last year. Eleven varieties were treated with an ester by Foster of Regina. He reported that Gopher, Vanguard and Valor were the most tolerant and Anthony the most susceptible. Ajax, Beacon, Brighton and Vanguard showed many head deformities. Other varieties included in the test were Garry, Victory, Banner, Exeter.

Breakey and Olson compared Thatcher, Redman, Regent and Carleton wheat at Morden, and Thatcher, Redman and Stewart at Winnipeg, Manitoba. Regent was the only variety that suffered significant reduction at Morden. The reduction was slight. Redman and Stewart showed slight damage at Winnipeg.

Heggeness and Letourneau, at St. Paul, Minnesota, compared Rival and Mida under four amine and one

ester formulation. Both Mida and Rival suffered significant yield reduction from the ester treatment. Two of the amine formulations reduced the yield of Rival.

In a test involving 11 varieties of wheat, Foster of Regina found Renown and Saunders most tolerant. Rescue and Thatcher were the most susceptible. The other varieties involved were Regent, Reward, Redman, Apex, Marquis, Cadet and Red Thatcher.

Trails with barley were reported by Olson and Breakey for Winnipeg, Manitoba and Foster for Regina, Sask. Montcalm showed the most consistant yield reduction at Winnipeg and Vanguard the least. Amine and ester were applied at 4 and 8 ounces acid per acre. Out of 14 varieties treated with ester at 8 ounces, Foster reported Warrior, O. A. C. and Compana most tolerant and Trebi, Prospect and Vanage most susceptible. The other varieties included were Montcalm, Olli, Regal, Colsess, Hannchen, Titan, Plush, Velvon and Compana. Evidently there is no agreement between the Winnipeg and Regina results.

Helgeson, at Fargo, North Dakota, treated Mida, Regent, Rival, Pilot breadwheats, and Mindum and Carleton durum at the fully tillered stage with ester amine and sodium salt at one pound acid per acre. No differential response of varieties was reported. Only the ester formulation caused any marked reduction in yield or other damage. Ester reduced the yield of all varieties by an average of 4 bushels, reduced the average height by 2 to 3 inches and caused a slight reduction in average test weight.

C. *Effect of 2,4-D on quality.*

Friesen, at Scott, Saskatchewan, treated wheat with three formulations at 4, 8, and 16 ounces per acre. The applications were made at four stages, namely pre-emergence, 3 leaf, shot blade and late flowering. This work was done in 1947 when growing conditions were unfavorable. Milling and baking qualities were not affected.

From trials at Bozeman, Montana, Warden reported effects on protein content in Thatcher, Ceres, Rescue and Supreme and Onas wheats treated with one-third, two-third and one pound of ester at early tillering and full tiller stages. There was a highly significant increase of protein with increased rates although the maximum increase was only .86 per cent. There was no evidence of differential responses between varieties.

D. *Effects of different herbicides.*

Pavlychenko, at Saskatoon, applied several commercial brands of 2,4-D to weed infested spring wheat, oats, barley and rye at two stages. One of these stages was described as "near the boot" and the other "24 days after emergence." The rates were 2, 4, 6 and 8 ounces acid per acre. Weedar 64 (amine salt of 2,4-D) was severe on all crops at both stages particularly at 6 ounces and above. ACP. 649 (2,4-D) did severe damage to oats and barley particularly at the 6 and 8 ounce rates. ACP. 648 (2,4-D) depressed all crops considerably at the "near boot" state. ACP. 472 (2,4-D) was beneficial to crops in some cases and caused little or no damage in any case. It also produced incomplete control of weeds.

Helgeson, in North Dakota applied butyl ester, E.H. No. 1 and L.F.N. 472 at several concentrations up to one pound per acre to Mida wheat at the tillering stage. No significant reduction or increase in yield, test weight or height of plant was noted for any of the treatments.

Buchholtz at Madison, Wisconsin, treated Clinton oats at 12 inches high with MCP in the form of sodium salt, amine and isopropyl ester and 2,4-D as the amine salt. The rates used were .25, .5, 1.0 and 2 pounds per acre. Significant reduction in yield was caused only by the 2 pound rate of 2,4-D. Yields under treatment with MCP were significantly higher than under 2,4-D. No significant differences were found between the MCP preparations.

E. *Effect on weeds in cereals.*

Ficht, at Swift Current, Saskatchewan, applied triethanolamine, alkanolamine, butyl ester, ethyl ester and sodium salt, at 2, 4, and 16 ounces for the amines and ester and 4, 8 and 32 ounces for the sodium salt to wheat, oats and barley infested with Russian thistle. The applications were made at two stages, namely beginning of tillering (five to six weeks after seeding) and "near shot blade," thirteen days later. Sodium salt gave no appreciable control except at 32 ounces. Some of the 4 ounce and all the 16 ounce treatments of the other formulations gave complete control. Yields of the crops were decreased markedly under the 16 ounce treatments. Sexsmith, at Lethbridge, Alberta, treated wheat and barley, which had a heavy infestation of Russian thistle. Applications of ester and amine were made at 5 dates: the first when the Russian thistle was 1 inch tall in the "pine leaf" stage and the last 29 days later when they were up to 2 inches tall. Weed control increased with increased rates and decreased with delay in treatments. Very satisfactory control was obtained with all treatments at the first stage and will all but the 2 ounce ester treatment at the second stage. Treatments at the later stages gave unsatisfactory results.

F. *Effect on clovers and alfalfa sown in small grain.*

A mixture of alfalfa, red clover and ladino clover was sown with Thorne wheat and Clinton 59 oats by Shaw and Willard in Ohio, and treated with Amine and ester. The applications were made at 10 stages in wheat and 9 in oats, these including pre-emergence in each case.

Rates of application ranged from ¼ to 4 pounds acid per acre. Legume stands were practical failures at the stages recommended for weed control. The authors conclude that treating with 2,4-D is not to be recommended in the case of small grains with which legumes have been sown.

Taylor, at Agassiz, B. C., treated oats which had been seeded to clover. All treatments showed a significant reduction in stand of clover except the 2 ounce ester treatment, and the Dow Selective at 1 and two thirds quarts per acre. The rate of survival ranged from 92.7 to 21.8 per cent as the rate of application of ester increased from 2 to 8 ounces.

Effect of Some Selective Herbicides on Fall Planted Small Grains

W. M. Phillips

Annual weeds usually are not a serious problem in fall planted small grains as compared to spring planted grains. Normal fall emergence and growth enables the grains to compete successfully with the weeds and thus precludes the necessity of spraying. It is not to be implied that there are never weeds in the winter wheat belt. Some weedy fields and even weedy areas are to be found each year. Sub-normal rainfall over much of the Southern Great Plains in the fall of 1947 and in some areas in 1948 resulted in an annual weed problem over rather large areas in 1948 and 1949. The past two years have seen tremendous expansion of interest in spraying winter wheat. Hundreds of farmers in the area have added sprayers as a part of their necessary farm equipment. Commercial ground and airplane operators abound in the area.

This year research workers in five states submitted abstracts of results achieved from spraying winter wheat. By studying these reports and reports of previous years, we find we still do not have all of the final answers; but we are collecting an immense amount of data which when put together gives an increasingly complete picture of the problems of spraying fall planted small grains.

Several investigators sprayed wheat with both 2,4-D and 2,4,5-T. The two chemicals appeared to cause similar reactions in the wheat plant. Other investigators have shown 2,4-D to be fully as effective as 24,5-T in controlling most annual weeds. Because of the present price differential there seems to be little place for 2,4,5-T in the wheat spraying program. For this reason the remainder of my remarks will be confined to 2,4-D.

This year, as in the past, there were variations in the results obtained at different locations. Some investigators found wheat rather resistant to 2,4-D when treated at several stages of spring growth. However, another contributor obtained a significant reduction in yield with as little as ¼ pound 2,4-D applied during the late jointing, early heading, and blooming stages. These latter results are in accord with the general recommendations of the past. While it appears that wheat sometimes may be injured in nearly any stage with relatively low dosages of 2,4-D, the period from late jointing to kernel formation seems to be the most susceptable stage of growth. It is true that wheat has been treated during these stages without injury, but the incidence of injury is greater during this period of the plant's development than at other stages. It is well agreed among the various investigators that fall applications were quite injurious to winter wheat this year. In some cases the reductions in yield exceeded 50 per cent as a result of these fall treatments.

Perhaps there should be some clarification of the need for fall applications. It has been found that when good growing conditions prevail, treatment with 2,4-D in the fall has given quite satisfactory control of field bindweed and other noxious perennial weeds. If it were possible to spray wheat in the fall, the bindweed eradication program should be more effective on those wheat farms infested with this troublesome pest. However, in view of the serious reduction in yields it seems inadvisable to recommend fall treatment.

Under some conditions it may be desirable to treat bindweed in growing wheat in the spring. There are one or two serious disadvantages to such applications. First of all, the bindweed in much of the Southern Great Plains region will be in the proper condition for treatment at about the time the wheat reaches the boot stage. A second disadvantage is that wheat often will not tolerate dosages large enough for maximum control of bindweed without some damage to the crop. Such damage may not exceed the reduction in yield which the bindweed would cause.

As has been the case in other crops the question of varietal differences in winter wheat has arisen. Several investigators sprayed a number of different varieties and selections of winter wheat in 1949. One team of investigators reported significant differences in the reactions of different varieties to 2,4-D. Another indicated the possibility of different responses at two stages of development. Others reported some rather definite indications of varietal differences, but preferred to do additional work before making positive statements.

As has been reported previously the esters appear to be somewhat more efficient in controlling annual weeds, especially in the drier areas of the winter wheat belt. In 1949 one cooperator reported that pound for pound a sodium salt was no more than 50 per cent as effective as an ester in controlling annual weeds in winter wheat.

During its most resistant stages of growth, wheat generally will tolerate dosages of 2,4-D necessary to give excellent control of most annual weeds commonly found in the crop. If spraying is accomplished early in the season, before the wheat reaches the boot stage, the weeds are generally small and may be controlled with ¼ to 1/3 pound 2,4-D as an ester, or nearly twice that amount of amine or sodium salt. As the weeds increase in size, of course, it becomes necessary to increase the dosage of 2,4-D.

During the past two seasons there have been rather large acreages sprayed just prior to harvest. At this time the annual weeds are large and approaching maturity. Results of treating so late in the season have been variable. Since more 2,4-D is necessary at this late date, the cost per acre is considerably increased.

None of the contributors reported significant effect on germination of winter wheat as a result of treatment with 2,4-D. Three stations reported on the effect of 2,4-D applications on protein content of winter wheat. In general, it may be said that as the yield was reduced by 2,4-D the protein content was increased. One investigator reported an extremely close correlation between these two factors in one experiment. According to one abstract there appears to be a possible varietal difference. Extensive quality tests conducted at one experiment station on wheat harvested from plots treated with 2,4-D in 1948 failed to show any effect on milling and baking quality of the wheat.

Total ash determinations also failed to show any differences between treatments.

This summary was to cover fall sown barley and oats as well as wheat; however, only one investigator reported on these two crops. It was indicated that barley was injured more severely than wheat by fall applications, and that oats appeared to be even more susceptible to injury than barley.

SUMMARY

Weeds usually are not a serious problem in fall planted small grains; however, it is expected that there will be a substantial acreage sprayed each year. In 1948 and 1949 winter wheat was generally more heavily infested with annual weeds than is normally the case.

Research work up to and including 1949 has indicated that fall applications of 2,4-D nearly always cause some reduction in wheat yields. Although several investigators have treated winter wheat at various stages in the spring without injury, lower yields as a result of 2,4-D applications are not uncommon. The wheat plant appears to be most susceptible to injury during the boot and early heading stages. Rates of application high enough for control of perennial weeds may cause damage to the wheat.

When the 2,4-D formulations are applied at corresponding rates the esters appear to cause more crop damage than the salts. The esters have also been more effective in controlling annual weeds. No appreciable difference has been noted between 2,4-D and 2,4,5-T when applied to winter wheat.

There are indications of varietal differences in winter wheat, but additional work will be necessary to determine these differences accurately.

Germination of wheat from plots sprayed with 2,4-D has not been affected to any extent. Protein content has been increased by the use of 2,4-D only when yields were decreased. According to one abstract, milling and baking qualities are not affected by 2,4-D applications.

Effects of 2,4-D and Other Herbicides on Flax

R. G. Robinson

Much of last summer's research supported the results of previous trials. Formulations can still be ranked in decreasing order of potency as follows: ester, amine salts, and sodium salts. Varietal differences in response to 2,4-D were again found by several investigators. Dosages were, in general, lower than those of two or three years ago, but desirable amounts varied among the different trials reported. Flax sprayed in bud or bloom stages has continued to be very severely injured. Delayed blooming, delayed maturity, and morphological symptoms continued to be widely reported. Germination of seed from flax sprayed at recommended dosages and stages was generally uninjured. The effect of 2,4-D on the iodine number of the oil and on the oil content of the seed is still unsettled, although limited trials this year indicated that there was not much effect at recommended dosages and stages.

MCP (Methoxone, Agroxone) was less injurious to flax than amine or ester of 2,4-D at the same dosages and controlled wild mustard in Minnesota and Frenchweed in Saskatchewan at 4 ounces.

Within the ester and amine formulations of 2,4-D, there are many types such as butyl and ethyl esters or isopropyl and triethylamines. Also different additives and "carriers" of the active ingredients are used. Recommendations for flax have, in general, been based on the assumption that all amines were alike and all esters alike in their effect. Heggeness and LeTourneau have reported that amine formulations differ in their effects on flax, and Heggeness reported to the Flax Institute that there were wide differences in the response of flax to different ester formulations. Increasing attention will have to be given to this phase of research in making general recommendations.

A few years ago farmers were told that flax was susceptible to 2,4-D and warned against using it on this crop. The present widespread use of 2,4-D is not due to a change in the susceptibility of flax. It still is just as susceptible as it was then. The yield increases obtained by spraying flax have been due to the reduction of weed competition.

Under weed-free conditions in trials conducted by the Minnesota Agricultural Experiment Station, flax sprayed with 2,4-D has on the average yielded less than unsprayed flax. However under weedy conditions, yield increases have been obtained with dosages up to the level at which the benefits of weed control were offset by the damage done by the chemical. For example, flax heavily infested with moderately resistant weeds such as wild buckwheat and smartweed has been severely injured by 2,4-D and still surpassed untreated flax in yield because of the lessening of weed competition.

Concurrently with the elimination of the non-grass weeds, foxtail and barnyard grasses have increased, as measured by dry weights at harvest. However this increase has not been enough in Minnesota trials to offset the benefits of controlling susceptible weeds such as mustard.

Time of application was found to be important in studying varietal differences in response to 2,4-D. Davidson and Foster reported that the relative resistance of varieties changed between different times of application.

Most spraying is done after flax has several true leaves but well before bud stage. Within this period large differences in resistance occurred, but reports differed as to the times of greatest resistance and susceptibility. One difficulty in comparing results is that time of application is not uniformly described. Designation varied from number of days after emergence to number of leaves, height of flax, and/or stage of growth of the flax. Rate of growth near the time of spraying is probably an important factor, or as Paatela of Finland has suggested, *variations in resistance at different times of application may be negatively associated with variations in the natural auxin content of the flax plant.* Paatela reasons that since 2,4-D is a growth regulating substance, flax may be susceptible when it contains an abundance of

auxin and resistant when it is low in auxin. If this theory is sound and since agronomists and farmers would probably use growth rate rather than auxin content, the relationship between auxin content of flax and environment, growth stage, and rate of growth needs further investigation.

This year's abstracts indicate that varieties cannot be satisfactorily classified as resistant or susceptible on a regional basis at the present time because the same varieties were not grown in the different locations, and the basis of classification was not uniform. Coupland reported that varieties most susceptible as ranked by delay in maturity were most resistant when ranked according to decrease in seed yield.

Delays in maturity from spraying at recommended dosages and stages have not been serious, although there are occasional reports of greatly delayed maturity. Even unsprayed flax has under certain environmental conditions a tendency to become indeterminate and bloom late in the fall. This characteristic could easily be confused with 2,4-D injury unless check plots were available for comparison.

A new morphological symptom of 2,4-D was reported by Warden. Some of the seed from flax sprayed in early bud failed to develop cotyledons while the seed coats developed to almost normal size. Such seed coat development did not occur in hand emasculated flowers, so Warden suggests that ovule abortion following fertilization may have occurred.

It is quite possible that most of the germination tests on sprayed flaxseed were made during the fall and winter after harvest, so that a possible differential rate of deterioration may have been overlooked. Heggeness and LeTourneau reported that seed from sprayed flax, especially at higher dosages, showed a decreasing capacity to germinate when stored for various periods of time. This effect was also evident when some of the seeds were planted in the field after 8 or 9 months of storage.

A study has been conducted at the Minnesota Agricultural Experiment Station for the past two years to determine if 2,4-D caused hereditary changes in flax. The first and second generation progeny of flax sprayed at various stages and dosages in 1947 were studied in 1948 and '49, respectively. Seed and straw yields of the progenies of the sprayed and unsprayed 1947 flax were not significantly different. Furthermore, there were no differences in abnormalities, seed germination, oil content, or iodine number of the first generation. Work on the second generation has not been completed at this time.

Use of Herbicides on Seedling and Established Legumes

K. P. Buchholtz

Leguminous crops have usually been considered so sensitive to most herbicides that these materials could not be recommended for use in these crops for weed control purposes. An exception has been the use of dinitro sprays on legume seedings. Originally cresylate dinitro compounds were used. These materials did not reduce stands of red clover and alfalfa seedlings materially, but appeared to be too toxic for use in grain having seedings of sweet clover. The phenate type of dinitro preparation came into use about 5 years ago. These materials are even less toxic to legume seedings than the cresylate compounds. Stands of red clover and alfalfa have seldom been reduced more than 20 per cent by their application. Sweet clover may also be treated safely. The main precautions to be followed appear to be delaying application until the seedlings have several true leaves and using no more than recommended rates of application. Canning peas have likewise been treated successfully with the dinitros now on the market. Control of small annual broad-leaved weeds has usually been achieved by such treatment. Canada thistle growth in peas has occasionally been affected severely enough so that date of budding has been delayed. This has resulted in fewer thistle buds in the shelled peas. Such a response has not been consistent enough however, to warrant widespread recommendation.

The use of dinitros has never become as widespread as might be desired. The somewhat erratic herbicidal effect on annual weeds, lack of action on perennial weeds, apparent need for application in large quantities of water and disagreeable handling characteristics have greatly limited the use of dinitro sprays even though it appears that leguminous crops can be treated safely.

In many areas of the North Central region small-seeded legumes are commonly planted in grain crops. Often as much as 75 per cent of the grain planted may contain a legume seeding. If herbicides are to be used widely in such areas it is mandatory that methods of application be adapted or materials be used that are not seriously injurious to the legume seedings. The abstracts submitted this year indicate that under at least some conditions seedling stands of medium and mammoth red clover, alsike and ladino clover, alfalfa and sweet clover in grain might be treated with herbicides of the growth regulator type without serious injury to the stand. Some experiments have also shown the possibility of treating Korean lespedeza, canning peas and soybeans with growth regulant herbicides.

It is well known that small legume plants may be killed easily by applications of 2,4-D and similar herbicides. When grown in grain plantings, however, the response of the legumes is modified considerably and they often survive treatment. The results from the various cooperators have not been entirely consistent. It is apparent that all conditions causing variation in results have not yet been recognized. Species of legumes vary considerably in their tolerance to 2,4-D. In three trials sweet clover was found to be more sensitive to 2,4-D than any other legume tested. In all trials in which they were included ladino clover and alsike clover were as tolerant or more tolerant than any other legume. Red clover was usually considerably more tolerant of 2,4-D than alfalfa. In one trial in Minnesota the reverse was true. The probable order of increasing susceptibility is ladino clover, alsike clover, red and mammoth clover, alfalfa and sweet clover.

The type of preparation used noticeably affects the

results obtained. In all comparisons made the sodium salt and amine preparations of 2,4-D were less toxic to the legumes than the esters when applied at equal rates. This was particularly true for the more sensitive legumes where the differences were sometimes very large. In several trials at Wisconsin ¼ lb. of ester per acre has resulted in as severe a reduction in stands of alfalfa as have ¾ lb. applications of the sodium salt and amine preparations of 2,4-D.

Differences in the effects of MCP, 2,4-D and 2,4,-5-T have likewise been shown. MCP appears to be noticeably less toxic to red clover, alsike and sweet clover than does 2,4-D. Results with alfalfa and ladino clover show MCP to have about the same effects as 2,4-D on these crops. It is probable that 2,4,5-T is more toxic to legume seedings than 2,4-D. Observations on sweet clover, red clover and alfalfa are available and all are injured more severely by 2,4,5-T than by 2,4-D.

Date of application undoubtedly has an effect on seedling response. The results from the different cooperators are not entirely consistent so it is likely that environmental factors not yet recognized are operating. It is generally advisable to delay the herbicidal applications enough to allow the legume seedlings to make at least several inches of growth. Waiting until the grain is 8 to 10 inches high before spraying has generally given better results than earlier applications. Later applications will probably give good stands of legumes but are far past the most desiarble time of treatment for weed control.

A low rate of application is probably more important than any other factor when legume survival is desired. Use of but ¼ lb. of 2,4-D has usually resulted in stands of 50 per cent or more of check stand of even the most sensitive legumes when other factors were favorable. Some abstracts indicate that as much as 1 lb. of 2,4-D may sometimes be used without appreciable injury to the legume stands. Results so far obtained have varied widely in different localities. Poor results are reported from Ohio, fair results were obtained in Michigan, Minnesota, and South Dakota, and satisfactory results from Wisconsin. Regions within states likewise vary for it is known from results in farmers fields that legume seedlings are maintained more successfully in Eastern Wisconsin than in the western part of the state.

There are indications that old stands of alfalfa may be treated safely with herbicides if the applications are made during the early spring when the alfalfa plants are somewhat dormant. Possibly the marked translocation of reserves from the roots of the alfalfa plant during this period prevents any of the herbicides from being distributed throughout the plant. An abstract from Nebraska describes the application of 1 lb. of 2,4-D as the sodium salt to alfalfa in the early spring without injury to the alfalfa. Broad-leaved weed growth was controlled 90 per cent by this treatment and growth of grasses 60 per cent.

Further trials should be made on the use of 2,4-D and similar materials for weed control in peas. Yields of shelled peas were not reduced by applications of ¼ lb. of the amine or sodium salt of 2,4-D when applications were made prior to bloom. Use of 1/2 lb. of 2,4-D caused some reductions but they were usually not significant. Applications of the ester of 2,-4-D affected the pea growth so severely that no yields were obtained whenever ¼ lb. was applied. Peas appeared to respond to MCP, 2,4-D and 2,4,5-T in a similar manner. Application of the herbicides after blossoming had started resulted in a marked reduction in yield. This was due to the failure of many of the pods to develop normally. Inflated pods without seeds were common after this treatment. Broad-leaved weed control could be achieved at the rates tested and the growth of even perennial weeds would be retarded by such an application. The practice cannot be recommended at present but is worthy of further work.

Information from Oklahoma indicated that many weeds in fields of Korean lespedeza may be killed by making application of 2,4-D at several stages of growth prior to bloom. Seed yields of the lespedeza were but slightly affected by applications of as much as 1 lb. of 2,4-D per acre. Ester preparations caused a greater yellowing of the lespedeza leaves than did the use of amines but seed yields were not noticeably different. It should be noted that applications were made during hot, dry conditions which may have increased the tolerance of the lespedeza.

In one trial in Illinois the ester of 2,4-D in diesel oil was used in an attempt to kill cockleburs in soybeans. An application was made as the soybean leaves were starting to yellow. Defoliation of the soybeans was completed within 48 hours. No pronounced injury to the cockleburs was obtained for they were nearly mature. Yields were not affected. Applications of 2,4-D to beans that were only 2/3 mature speeded their development and reduced the seed size. From these results it appears that 2,4-D may have a place as a defoliant for soybeans.

It is probable that 2,4-D and related materials can be used for weed control in legume seedings, peas and Korean lespedeza if the weeds involved do not require high rates of application for their control. A number of factors such as growth stage, material, preparation and plant specie are known to affect results. Local conditions also appear to be highly important. These conditions may at times increase the injury to legumes to the point where the use of herbicides would be of no practical importance if stands of the legumes must be maintained.

Effects of Herbicides on Seedling and Established Grasses

Dayton L. Klingman

Reports of chemicals for weed control in grasses were limited in number. The reports indicate need for further critical studies to evaluate the usefulness of chemicals, both in seedling establishment and in established stands.

2,4-D can be used advantageously for broad-leaved weed control in seedling grasses if the weedy grasses are not a problem in the area. Under such conditions the spring-planted grasses gave marked responses in growth vigor the year following treatment with 2,4-D for weed control when compared to an un-

treated check or to a mowed check.

When 2,4-D was applied in the spring to late fall sown grasses for annual weed control at rates of one to two pounds per acre, the resulting stands were more uniform and more vigorous as a result of the removal of weeds (scattered plants of wild buckwheat not controlled).

Rates as high as one pound ester per acre were applied to seedling and newly established grasses for perennial weed control. Fall treatment of white cockle gave better control than spring treatment, but the fall treatment retarded the growth of grass slightly. Treatment either in fall or spring to well-established creeping red fescue gave no observable damage and good control of blue lettuce when applied at the bud stage at one pound ester per acre.

In areas infested with both broad-leaved weeds and weedy grasses, the use of 2,4-D was effective only in changing the type of weed competition. It is thought that the weedy grass competition was fully as detrimental to seedling grasses as were the broad-leaved weeds present on the untreated plots.

When six species of grasses were treated with one-half and one pound amine salt in greenhouse tests, injury resulting in reduction of stand occurred when the grasses were sprayed at emergence, the warm-season grasses included in the test being injured the most. All grasses at eight weeks following emergence were tolerant of the spray.

Twenty-eight day old *Agrostis canina* seedlings were given an extremely high rate of 2,4-D soil treatment in order to study anatomical responses. Ten days after treatment plants resembled young onions. Root systems were smaller, protuberances upon primary roots were observed, and leaves were seriously injured. The number of root initials was greatly increased both in the swollen base of the plant and along the primary root.

Alfalfa, two months after seeding, was sprayed with three ounces 2,4-D (ester) per acre. This treatment halted the heavy growth of Russian thistle, caused temporary curling of alfalfa seedlings, but these quickly recovered.

Questions as to toxicity of herbicides to livestock are frequently asked. Such information about dinitrophenol, pentachlorophenol, trichloroacetate, 2,4-D, and 2,4,5-T is reported. The grass-alfalfa mixture sprayed was grazed by horses, cattle, swine, and chickens. No injuries to the livestock were observed. Forage plants recovered from treatment with dinitro and PCP, alfalfa was destroyed by 2,4-D, and 2,4,5-T, and all vegetation was destroyed by TCA.

2,4-D may be used advantageously in established grasses at the rates necessary to control moderately susceptible weeds. Many of the grass species may be sprayed as seedlings with 2,4-D.

Effects of Selective Herbicides on Sugar Beets

E. A. Helgeson

In March of last year a Regional Conference on chemical weed control in sugar beets was held in Fargo, N. D. The purpose of this meeting was to design a uniform experiment in which the various cooperating agencies could participate during the summer of 1949. In attendance were representatives from several Canadian provinces, Iowa, Michigan, North Dakota, the U. S. Dept. of Agriculture, Sugar Beet Foundation and the American Crystal Sugar Company. Minnesota and Ohio were invited but were unable to send representatives. I shall not burden you further with details of this conference nor with the characteristics of the experimental plan finally evolved, other than that we decided all should use uniform rates of application of some 15 chemicals for pre-emergence control and about 10 chemicals for post-emergence studies. Applications for pre-emergence work were to be applied at seeding and 4 days later. Post-emergence sprays were to be applied just after thinning, which with us at Fargo was 29 days after planting.

Now as to results: I think it may be best to report on pre-emergence studies first and I shall therefore outline results with each individual chemical used.

NaTCA at 10 and 20 lb. rates had little effect on stands and gave fair weed control. Thirty and 40 lb. rates caused serious injury to beets with slightly enhanced weed control (Michigan and North Dakota reports).

According to Michigan and North Dakota results, dinitros in water or oil at rates from 1 to 2 lbs./A reduced beet stands without controlling weeds.

E.H. No. 1 at 1 to 4 lb. and E.H. No. 2 at 2 to 8 lbs./A reduced beet stands slightly at Fargo with fair weed control, whereas Anderson and Shadbolt of Manitoba reported these compounds ineffective on either beets or weeds.

Applications of 2,4-D at rates up to 2 lbs./A were injurious to beets in Alberta, Manitoba, Michigan and North Dakota with fair weed control in all locations except Michigan.

Reports from Manitoba and North Dakota showed no effect on weeds or beets with IPC; Michigan reported good weed control with this chemical, with no damage to the crop from aqueous sprays but a 60% reduction of stand where oil was the solvent (rates 5-20 lbs.).

Aerocyanate at 10 to 30 lbs./A was entirely ineffective.

Polybor at 320 lbs./A reduced beet stands slightly, caused mild distortion and chlorosis of leaves, but gave fair weed control. At 640 lbs./A weed control was good but beets showed some injury (N. D. and Manitoba Rpts.).

In the Fargo trial Chlorosal A at rates up to 80 lbs./A affected neither crop or weeds. PCP proved fairly effective against weeds in Michigan and North Dakota but not in Manitoba. Beet stands and vigor were affected adversely.

NaPCP did not control weeds in the Fargo or Manitoba trials but did reduce beet stands at Fargo. Sexsmith of Alberta reported 80 per cent weed control, a reduced beet stand but an increased yield of beets for this chemical when applied at a rate of 40 lbs./A.

Fargo trials yielded fair grass control but not broadleaf weeds and beet stands were reduced, with 3 and 5 qt. rates of XP39A and Fargo and Manitoba both found XP40A ineffective.

Sulfasan affected neither beets nor weeds at Fargo. Sexsmith (Alberta) reported good weed control with this chemical at 40 lbs./A but a severe beet stand reduction. At 5 lbs. he found increased beet yields but does not mention weed control.

Turning now to post-emergence results it is obvious that our choice of chemicals is limited. To control broadleaf weeds in a broadleaf crop such as the sugar beet without injury to the latter presents many problems of a basic physiological character about which we have little or no experimental background. Unfortunately we had only single scatteerd reports on a number of these which emphasize the importance of regional cooperation.

Sulfason at 1, 2 and 4 lbs. and Chlorosol A at 10, 20 and 40 lbs. burned beet leaves slightly but failed to control weeds. Grigsby and Swanson et al. reported some weed control with NaTCA at rates over 10 lbs./A but beets were injured also at higher rates. Anderson et al. (Manitoba) and Grigsby obtained fair to good broadleaf weed control with NaCl at 200 and 400 lbs./A acre. Considerable beet injury resulted from 600 lbs./A rates. At Fargo NaCl was entirely ineffective. Cupric nitrate or chloride caused severe injury to beets at 10 and 20 lbs./A with fair to good broadleaf weed control. Beets at Fargo and Manitoba made a poor recovery. In Michigan fairly complete recovery occurred. ZnSo4 at 20 lbs./A was ineffective at all 3 stations.

Aerocyanate at 5 to 15 lbs./A caused severe injury to beets at Fargo and Manitoba with indifferent weed control.

Grigsby reported satisfactory weed control with KCl at 100 and 200 lbs./A while 400 lbs. killed beets in the 2 and 4 leaf stage.

Polybor at 160 and 320 lbs/A controlled pigweed (*Amaranthus retroflexus*) satisfactorily, stunted false ragweed(*Iva xanthifolia*) with only slight injury to beets.

XP39A at 2 and 4 qts. retarded beets at Fargo with no weed control. EH No. 2 at Manitoba affected neither crop nor weeds.

In summary it is evident that we have not as yet found any entirely satisfactory herbicide for use in sugar beets. For pre-emergence work NaTCA, IPC, Polybor, NaPCP and Sulfasan show some promise and for post-emergence weed control Cupric nitrate, NaTCA, NaCl and Polybor may merit furthur study.

The Use of 2,4-D for the Control of Weeds in Strawberry Plantings

R. E. Nylund

Since Carlson (2) first reported on the reaction of 13 varieties of strawberries to 2,4-D and the possibility of the use of 2,4-D for the control of weeds in that crop, a number of reports have appeared on this subject. A number of workers (2, 3, 5, 6, 8, 9) have shown that while varieties of strawberries differ in tolerance to the action of 2,4-D, the differences in tolerance are not important within the range of 2,4-D concentrations necessary for satisfactory weed control. Carlson, in his earlier report (2), suggested the use of 1000 ppm. of 2,4-D and in a later report (3), ¼ to 1/2 lb. of 2,4D acid per acre. Neville, et al (6) used the sodium salt and ester formulations of 2,4-D at rates ranging from 1/2 to 2 lbs. per acre with no differences in final effect on the strawberry plants. Slife and Ball (8), who applied an amine at rates from 1/2 lb. to 3 lbs. 2,4-D acid per acre on the variety Premier reported that the higher rates of 2,4-D caused greater growth effects but that all plots were normal in appearance after one month. Gilbert (5) reported that 2 lbs. per acre of 2,4-D acid as a pre-planting treatment and 1 and 1/2 lbs. 2,4-D acid per acre as post-planting treatments gave good weed control without injury to strawberry plants. Carder (1) used 8, 16 and 32 oz. (acid equivalent) of butyl ester of 2,4-D on the Dakota variety just prior to flowering, at flowering, and in late summer after harvest. Only the 32 oz. rate when applied at flowering time caused injury to the strawberry plants. Davidson (4) applied 1/2 lb. and 1 lb. of 2,4-D acid in the forms of the sodium salt and an amine and reported that while the 1 lb. per acre rate produced slight formative effects later growth and fruiting appeared normal.

The present paper is a report of the repeated application of 2,4D on weed control and on the growth and yields of strawberry plants. A preliminary report (7) on this study has been published elsewhere.

MATERIALS AND METHODS

On June 21, 1948, strawberry plants of the June-bearing variety Arrowhead were planted at the Minnesota Fruit Breeding Farm at Excelsior, Minnesota. The soil, a heavy clay loam, had been prepared the day before planting. The following eight treatments were applied to single row plots 30¼ feet long in each of ten replicates, eighteen days after planting (July 9): sodium salt of 2,4-D at 1, 2, 3, and 4 lbs. acid per acre, isopropyl ester of 2,4-D at 0.25, 0.5 and 1 lb. of acid per acre, and untreated check. The air temperature at the time of the July 9 application was 85 degrees F. and the soil was wet, 0.44" of rain having fallen during the preceding 24 hours. Due to the reappearance of weeds in the 1 lb. and 2 lb. sodium salt plots and the 0.25 lb. and 0.5 lb. ester plots about 4 weeks after the initial treatment, these plots were re-treated on August 11. The air temperature on August 11 was 75 degrees F. and the soil was wet, 1.67" rain having fallen during the preceding 24 hours.

Weed stands were determined on July 14, July 23, and August 24 in each of the plots by counting all the broad-leaved weeds within the areas covered by a 6" x 20" frame laid down over the row at distances of 3' and 9' from the end of the plot. The principal broad-leaved weed species present were Red-root Pigweed (*Amaranthus retroflexus, L.*) and Purslane (*Portulaca oleracea, L.*). The untreated check plots were hand-hoed on July 14 and on August 24 and grasses were pulled from all plots on those dates.

The number of leaves per mother plant was determined on August 11 by counts made on five plants in each plot in five of the ten replications. Similarly, the effect of the 2,4D treatments on runner plant formation was determined by counting all of the

rooted runner plants arising from five mother plants in each plot in the first five replications. Runner plant counts were made on August 11 and on October 21.

On June 6, 1949 the seven 2,4-D treatments which had been used in 1948 were repeated on the plots in five of the ten replicates. The air temperature at the time the herbicide treatments were applied was 70 degrees F. and the soil was fairly moist, approximately 1 inch of rain having fallen during the preceding five days. Most of the crop of fruit was set as some fruits were as large as 1 inch in diameter and only a few blossoms were present.

The 2,4-D treatments in both 1948 and 1949 were applied as sprays using 80 gallons of water per acre. A knapsack sprayer fitted with a fan-type nozzle having an orifice .059 inch in diameter was used for all treatments.

All fruit from both the 1948-treated and the 1948-plus 1949-treated plots and check plots were harvested during the period from June 14 through June 29 in 1949.

EXPERIMENT RESULTS

The effects of the 2,4-D treatments applied in 1948 on stands of broad-leaved weeds are given in Table 1. Weed counts taken five days after the July 9 treatment showed that few of the weeds had yet been killed. By July 23, however, all of the 2,4-D treated plots showed a reduction in number of live weeds. The 1 pound application of isopropyl ester and the 2, 3, and 4 pound rates of sodium salt had done an excellent job of weed control. The reappearance of weeds on the plots treated with the lower rates of 2,4-D made it necessary to re-treat those plots on August 11. Weed control again was good and all the re-treated plots and those treated only once remained relatively free of weeds for the remainder of the growing season.

Table 1 — Stands of broad-leaved weeds after application of various rates of 2,4-D in 1948.

Herbicide treatment:			Number of broad-leaved weeds per rod row on:		
Formulation	lbs. 2,4-D per acre	Dates Applied	7/14	7/23	8/24
	0		192*	5	87*
Isopropyl ester	0.25	7/9 & 8/11	207	104	16
Isopropyl ester	0.5	7/9 & 8/11	151	68	15
Isopropyl ester	1.0	7/9	134	11	7
Sodium salt	1.0	7/9 & 8/11	118	46	9
Sodium salt	2.0	7/9 & 8/11	151	19	2
Sodium salt	3.0	7/9	89	1	71
Sodium salt	4.0	7/9	131	2	71
	L.S.D., 5% level		49	25	14
	L.S.D., 1% level		65	33	19

*Untreated plots hoed on 7/14 and 8/24 after weeds counted.

Table 2. — Numbers of leaves and runner plants on strawberry plants treated with various rates of 2,4-D.

Herbicide treatment:			Number leaves per strawberry plant on	Number rooted Runner plants per plant on*	
Formulation	Dates Applied	lbs. 2,4-D per acre	8/11*	8/11	10/21
	0		7.2	3.0	7.8
Isopropyl ester	0.25	7/9 & 8/11	7.1	3.0	11.4
Isopropyl ester	0.5	7/9 & 8/11	6.3	2.3	8.7
Isopropyl ester	1.0	7/9	7.2	3.2	9.0
Sodium salt	1.0	7/9 & 8/11	7.4	2.5	10.4
Sodium salt	2.0	7/9 & 8/11	7.2	2.6	6.2
Sodium salt	3.0	7/9	7.0	2.0	7.1
Sodium salt	4.0	7/9	7.2	1.6	8.1
	L.S.D., 5% level		n.s.	n.s.	3.2
	L.S.D., 1% level		.....	.....	4.3

*Data given are means of 5 replications and are based on counts of 5 plants in each plot.

All of the 2,4-D treatments caused some leaf, petiole, and runner distortion but, as is indicated in Table 2, these growth effects did not adversely affect leaf production and runner plant formation. The runner plant counts made on October 21 indicate that the 0.25 lb. rate of isopropyl ester and the 1 lb. rate of sodium salt may have had a slight stimulatory effect on runner plant formation.

The effects of the 1948 herbicide treatments and the herbicide treatments at the end of the flowering period in 1949 on yields of fruit are shown in Table 3. Statistical analysis of the data showed that the differences in yield between those plots treated in 1948 only and those treated in both 1948 and 1949 are not significant. This is indicated by the mean yield of 14.1 quarts for the plots treated in 1948 and 14.5 quarts for those treated in both 1948 and 1949. The interaction "treatments x years" was likewise not significant. There were significant differences in yield between treatments. Some of the plots treated in 1948 only yielded significantly more than did the untreated check plots. Some of the plots treated in 1948 and 1949 yielded significantly less than did the untreated plots. The fact that rates of 2,4-D application as high as 1 lb. in the form of an ester and 4 lbs. in the form of the sodium salt did not result in reduced yields indicates that the reduced yields obtained from some of the plots treated with lesser amounts of 2,4-D are due to a factor or factors other than the herbicidal treatment.

Table 3 — Yields of strawberries in 1949 from plots treated with various rates of 2,4-D in 1948 and in 1949.

Herbicide treatment:				Yields of fruit (quarts per square rod) from plots treated in:		
Formulation	lbs. 2,4-D per acre	Dates Applied in 1948	in 1949	1948 only	1948 & 1949	Mean
	0			13.1	17.6	15.3
Isopropyl ester	0.25	7/9 & 8/11	6/6	18.2	16.1	17.2
Isopropyl ester	0.5	7/9 & 8/11	6/6	11.2	13.7	12.4
Isopropyl ester	1.0	7/9	6/6	17.0	17.3	17.2
Sodium salt	1.0	7/9 & 8/11	6/6	13.0	13.8	13.4
Sodium salt	2.0	7/9 & 8/11	6/6	10.1	11.0	10.5
Sodium salt	3.0	7/9	6/6	18.2	12.0	15.1
Sodium salt	4.0	7/9	6/6	11.9	14.8	13.3
		Mean		14.1	14.5	
		L.S.D., 5% level		5.0	5.0	3.5
		L.S.D., 1% level		6.7	6.7	4.7

SUMMARY

(1) A first year planting of June-bearing strawberries of the variety Arrowhead was treated with various rates of 2,4-D in the form of the isopropyl ester and of the sodium salt.

(2) One pound of 2,4-D acid (isopropyl ester) and 3 and 4 pounds of 2,4-D acid (sodium salt) satisfactorily controlled broad-leaved weeds from July 9 to the end of the growing season.

(3) Lower rates of the isopropyl ester (0.25 and 0.5 pounds) and of the sodium salt (1 and 2 pounds) controlled weeds for a period of about 5 weeks after which re-treatment at the same rates resulted in satisfactory weed control for the remainder of the growing season.

(4) None of the 2,4-D treatments resulted in reduced vigor of the strawberry plants as expressed by number of leaves and number of rooted runner plants.

(5) The 2,4-D treatments applied to strawberry plants during their first year in the field or applied during the first year and at the end of the blossoming period in the fruiting year did not result in reduced yields of fruit.

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Chickweed Control in Strawberries with IPC

R. F. Carlson and J. E. Moulton

The common chickweed, *Stallaria media* (*L.*) *Cyrill*, is an annual problem in many strawberry plantings in localized areas in Michigan and in many other states. Because of its crawling growth habit the chickweed soon spreads between the plants in the row, crowding them, and within a short time (four to six weeks) becomes matted over the entire field making it impractical to eliminate it by manual or cultural means. Consequently, the growers are in need of a selective herbicide that could be used safely and effectively to control the chickweed and save the strawberry planting for a second and third crop.

Since the chickweed is a winter annual most of the seed germinates in early September in Michigan. The seedlings grow and spread rapidly during the fall and early winter both in the open field and under a straw mulch. By early spring a large number of seeds are produced which remain dormant during the summer and germinate when the conditions are favorable in the fall. Thus, many first and second year strawberry plantings are infested with the weed.

MATERIALS AND METHODS

During the fall of 1947 several herbicides including 2,4-D (2,4-dichlorophenoxyacetic acid), Dow General (dinitro-ortho-secondary-butylphenol) and IPC (Isopropyl N-phenylcarbamate) were tried at herbicidal concentrations for the control of chickweed in strawberries. The "dinitro" compound was included because it appeared promising when applied in the fall on annual weeds in strawberries (6), and the 2,4-D because of the resistance of strawberry plants to it (1). Because IPC had exhibited selective properties on grasses and some broad leaved weeds it was also included (2, 3 & 4). It also had been found that IPC killed common chickweed when applied at low concentrations (3 pounds per acre) to a lawn overgrown with the weed (5).

From these preliminary tests in 1947 it was found that IPC controlled the chickweed; the Dow General "burned" the foliage of the weed and strawberry plants; and 2,4-D showed no visual effect on the chickweed. Therefore, in the fall of 1948 the tests were limited to IPC at four concentrations 5, 10, 15 and 25 pounds per acre and at different intervals (Sept., Oct. & Nov.). Two locations were chosen in Berrien County where the chickweed is a serious weed in many strawberry plantings. The soil type at one location was a Coloma sandy loam and at the other a Hillsdale sandy loam. The Robinson variety was grown at one location and the Premier at the other. Both plantings were started the previous spring (1948).

The technical grade of IPC was diluted with enough talc so that it could be dusted evenly over the strawberry row. The material was applied at both locations on September 20, October 22 and November 12. At the date of the first application the chickweed was in the 2-leaved stage; at the second it was spreading over the ground; and at the third it was matted in and between the rows. Flowering began at the second application (October 22). The strawberry plants were vigorous and had numerous runner plants. At the time of the first application, September 20, it is probable that they were still initiating flower buds since that occurs during the month of September and well into October in Michigan.

At both locations the plots consisted of twenty-five feet of the row and two rows were used for each treatment. The rows originally were planted four feet apart and at the time of the applications were in a matted row about 18 inches wide. The dust form of IPC was applied with a small hand operated duster. Care was taken to distribute evenly the dust over the entire row where the weed is difficult to remove by hand pulling or hoeing. The check rows were weeded by hand.

RESULTS

Effects on Chickweeds — At the time that the November applications were made the chickweed in the plots treated in September apparently were dead at the higher concentrations (10, 15 and 25 pounds per acre). At the lower rate (5 pounds per acre) about 20 per cent of the chickweed was still alive. The chickweed in the treated plots appeared grayish water-soaked as compared to the green vigorous growth in the check rows. The water-soaked appearance was most pronounced at the 2-3-inch basal portion of the stem. Many of the leaves were dark green with a leathery appearance, and considerably thicker than leaves from untreated chickweed.

The chickweed treated October 22, had begun to take on the slightly wilted and water-soaked appearance also at that time (Nov. 12). On December 15 similar effects on the chickweed were noticed in the November 12 applications at all rates. At that time the weed in the earlier applications had started to turn brown.

The following spring (April 15) all the chickweed in the 15 and 25 pound applications was dead and in the 5 and 10 pound rate about 80 to 95 per cent was controlled. This held true for all applications (September, October, and November) and the two locations.

Effect on Strawberry Plants — A slight marginal color change (yellow) of the younger leaves was observed in November on the plants that had been treated in September. This change was most noticeable at the high concentration (25 pounds per acre). This effect was noticed also in the spring on plants treated with the high concentration and at different times the previous fall. Flowering appeared normal and occurred at the higher rates per acre (25 pounds). No varietal differences were observed as to resistance to the material IPC.

November 20, two months after the September applications, 20 plants were dug from each treatment and checked and planted and grown in the greenhouse. At the time of transplanting, these plants were examined carefully for possible injury of the roots or crowns, but no visible ailments were noticed. These plants grew normally and fruited in March in the greenhouse. After they had fruited they were dug and examined further. It was noticed that the roots of the plants that had been treated with 25

pounds of IPC per acre were injured as was indicated by the dark color and the formation of a number of secondary roots at the base of the crown. The roots of the plants from the other treatments (5, 10 & 15 pounds per acre) appeared normal and vigorous, in fact, general appearance indicated an increased root system as compared to roots of check plants.

SUMMARY OF RESULTS

Four rates of IPC (5, 10, 15 and 25 pounds per acre) was applied at three different times (September, October and November) in 1948 and at two locations to chickweed growing in Robinson and Premier strawberries.

Satisfactory control of the chickweed was obtained at all concentrations and from various times of application. The chickweed at first exhibited a water-soaked appearance at the basal portions of the stem and turned brown and died after approximately two months from time of application.

The yield of treated strawberries was normal to that of check plants, except where 25 pounds per acre of IPC had been used. Some injury to the plants was also noticed at this high rate.

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Investigation of Weed Control Methods in Small Fruits

Glenn Viehmeyer

The number of abstracts submitted, if taken alone, are inconclusive and cannot be considered sufficient to serve as a basis for recommendations for the use of herbicides in small fruit crops, however, if they are used to supplement data from other sources and that reported at past conferences, certain recommendations seem possible.

Strawberries: Three cooperators reported on the use of 2,4-D for weed control in strawberries. These reports, when considered with those of past conferences and those received from other sources, indicate that the herbicide will effectively control broad leaved weeds in the crop with no permenant injury to the crop plant. Such use of 2,4-D can be recommended by the conference.

A single cooperator reports spraying strawberries in full fruit with no damage to the crop but others have reported misshapen fruit and blossom sterility from such treatment and it seems inadvisable to recommend treatment of fruiting plants without additional investigation.

It has been reported that IPC applied at the rates of 5, 10 and 15 pounds per acre did not injure strawberryy plants but that 25 pounds per acre caused some injury to strawberry roots. At dosages of 15 and 25 pounds per acre chickweed was completely controled. The 5 and 10 pound applications gave partial control. Additional investigation of this herbicide is indicated.

Raspberries: A single abstract reports on TCA for weed control in Raspberries. Dosages adequate for weed control resulted in serious injury to the crop plant. This agrees with past results and it appears improbable that TCA can be used to control weeds in fruit crops.

Orchards: A report on 2,4-D and 2,4,5-T for poison ivy control in orchards indicated that the latter is more effective for controlling this weed pest. The best kills were following July and early August treatments.

The same chemicals were used on horse nettle. Treatment during the early fruiting stage was most effective, with 2,4,5-T again being more effective than 2,4-D.

It is unfortunate that so few cooperators conducted investigations with chemical weed control in fruit crops and considerably more experimentation will be needed to determine the place of chemical weed control in fruit crops. When all sources of information are studied it appears that chemical weed control could play an important part in growing raspberries and strawberries.

Post-emergence Control of Weeds in Row Crops by the Use of Contact Sprays Applied with a Shielded Boom

J. D. Wilson and H. E. Bruner

The use of chemicals for weed control has been expanding rapidly during the past few years, following the sudden impetus furnished by the discovery of 2,4-D in its various forms. The selective nature of 2,4-D, with its special affirnity for broad-leaved plants, has made it especially useful in ridding the grasses and cereals of many of the weeds which are commonly associated with them in lawns, pastures, and fields. Most row crops, with the exception of corn, are broad-leaved species, and as such cannot be successfully treated with 2,4-D or most of the so-called contact weed killers.

In considering this fact, it occurred to the authors that it might be well to investigate the possibility of using a shielded boom to protect the crop plant from

the spray material being directed at the weeds growing between the rows. Such a spray boom, including both spray nozzles and shields might conceivably be constructed in various ways, but for the preliminarary trials reported here it consisted of three flat spray nozzles (T-jet 6704) with two pairs of intervening shields, all mounted on a three-eighths inch pipe assembly with an overall length of approximately 40 inches. This provided for the treatment of a swath 5 feet wide. The shields were made of 20-guage sheet aluminum and were 18 x 20 inches in size. The whole unit was then mounted on the front end of a stripped-down Myers wheelbarrow sprayer.

A Lobee gear pump with a capacity of 1¼ gallons per minute was attached to the top part on one side of the wheelbarrow frame. The pump was driven by a three-fourths horsepower gas engine mounted over the rubber-tired wheel. This wheelbarrow sprayer is commonly equipped with a 12-gallon tank, but since this was too large for use with the one-half to two-gallon lots of weed-killing formulations used in these experiments, a tall, narrow 4-gallon, heavily tinned, cream can was mounted inside the larger tank. The can was then calibrated in half-gallon increments. A 50-mesh screen placed in the top of the cream can, and a 50-mesh line strainer between the pump and the boom, served to reduce clogging of the nozzles to a minimum.

All of the various materials and formulations tested, of which there were about 40, were applied as water dilutions at 50 gallons per acre at a pressure of approximately 50 pounds per square inch. If a test chemical was not water soluble, it was prepared as a dispersion or an emulsion, by the use of a wetting or emulsifying agent. No special agitation was provided, but the liquid by-passed by the pump and the swaying and jarring motions of the wheelbarrow as it was pushed forward at a slow walk usually served to keep the spray mixture sufficiently well agitated.

Twelve different crops (principally vegetables) were used in these experiments but the tests were chiefly concentrated on sweet corn and soybeans since they quickly reached a size sufficiently tall for treatment. Most of the plantings were made on muck soil where about 10 species of weeds were present. Red root and purslane occurred most commonly during the months of June, July, and August, when the tests were made. The seeds were planted in paired rows, spaced 20 inches apart. Every third row was either not planted or was not protected from the spray material as it was applied. In treating the replicated trial plots, which were usually from 30 to 50 feet in length, the wheelbarrow was so aligned that the wheel was midway between the two rows being sprayed. The boom was so placed that the center nozzle was directly in front of the wheel and about 6 inches ahead of it. The shields were then mounted on the boom in pairs about midway between the center and each of the outside nozzles, with a space of 3 to 4 inches between the two members of each pair of shields. The crop plants were thus protected by a shield located on each side of the row and reaching nearly to the ground. If this method of treatment should come into general use, it seems likely that the shields should be mounted independently of the spray boom and be so attached that they might move up and down, but always kept a certain distance above the soil level by means of a roller or shoe. It is also suggested that the spray boom be constructed to match the lineal dimensions of any given assembly of planting units used in a gang or grouping. In this way, the plants in each row will always be protected by the similarly spaced shields, if the operator follows the proper course down the rows of a given swath.

The use of this type of equipment should serve to extend the scope of post-emergence weed control studies in the following ways,—

1. Decrease the importance of selectivity.
2. Expand the field of usable chemicals.
3. Increase the number of crops which may be treated.
4. Extend and make more flexible the time period during which spray applications may be made.
5. Permit more effective weed control through the use of higher dosages and thus increase herbicidal effectiveness.

As mentioned above, about 40 herbicidal formulations were tested, but the compounds most commonly used were Sulfasan, P.E.C., N.I.X., Dow Seletive, 2,4-Dow, Shell Weed Killer 130, Santobrite Fenester, Ammate, and Aerocyanate. Such materials as Sulfasan and P.E.C. were formulated in several different ways and nearly all of the compounds listed were used at more than one dilution.

A total of eight different experiments were performed during the summer of 1949. Data relative to only one of these are given in the following table to demonstrate the degree of weed control which was obtained when soybeans were sprayed with a shielded boom at the time the plants were about 4 inches high. These data represent the relative green weights of beans and weeds in plots treated with various chemicals when the beans and weeds were about 2 feet high. No cultivation was used between treatment and harvest.

Relative Weights of Soybeans and Weeds in Plots Sprayed with a Shielded Boom*

Treatment	Weight of Beans lbs.	Weight of Weeds lbs.
P.E.C. 2 gal. + 1265 5 gal.	55.8	21.9
P.E.C. 4 gal. + 1265 5 gal.	53.5	2.5
N.I.X. 12 lbs. + Aquarex ½ lb.	48.8	26.0
N.I.X. 20 lbs. + Aquarex ½ lb.	41.5	15.5
Sulfasan 1 gallon	32.3	42.5
Sulfasan 1 gal. + Oil 5 gal.	52.8	3.5
Sulfasan 2 gallons	46.0	22.5
Santobrite 10 lbs.	51.0	0.5
Shell 10 gallons	49.5	0.8
Dow Selective 2 quarts	30.0	48.0
2,4-Dow 1 quart	22.0	14.3
Check	15.0	108.0

* Average of two replicates.

These data indicate that all treatments gave some degree of weed control. All of the weeds, which were mostly red root or purslane, were removed from between the treated rows with Santobrite and Shell 130, as were many of those in the rows also. Four

pounds of P.E.C. in 5 gallons of oil (1265) also killed most of the weeds with only minimum damage to the beans. Two gallons were not sufficient. N.I.X. at 20 pounds per acre was somewhat injurious and Sulfasan at one gallon with no oil allowed too many weeds to survive and furnished competition for the beans. Adding oil to this material or using 2 gallons instead of one improved the control obtained to a considerable extent. Dow Selective used at 2 quarts per acre caused considerable injury to the beans and still did not kill all of the weeds.

The use of 2,4-D (the amine form) at one quart per acre gave comparatively good weed control but also caused injury to the beans; probably due to some drifting of the material onto the bean foliage in spite of the protective shields. This drift was not sufficient to injure corn in the same experiment. The check plots were so weedy that the beans were unable to develop normally.

The results obtained by spraying various row crops during the summer with a shielded boom suggest that this method of application should be of practical value in weed control practices. This is true chiefly because it makes possible the use of certain contact weed killers in post-emergence applications that could not otherwise be used, permits the use of more effective dosages, and extends the time over which control measures may be practiced. On this basis, further studies on boom construction, particularly on details concerning the mounting and placement of the shields, should be justified.

The Use of Sulfasan in the Pre-Emergence Control of Weeds in Row Crops

H. E. Bruner

The trade name Sulfasan is Monsanto Chemical Company's designation for ethyl xanthogen disulfide. It is not a new chemical and was synthesized by Monsanto's Rubber Service Dept. early in 1932 as one of a family of materials under investigation.

Had the war not created the need for synthetic rubber and the companion need for synthetic rubber accelerators, it is doubtful if Sulfasan would be active today. It was in 1942 that Sulfasan came off the shelf and began its life as an accelerator. Except for one fault it would have made the grade. that fault was its odor. Compounders didn't admire the "smell" and shortly refused to work with Sulfasan.

That turned out to be a fortunate occurance for had it not happened it is unlikely that another use would have been sought. Perhaps it was only natural that Monsanto should turn to agriculture in an attempt to develop a use for this chemical. The Ohio Agricultural Experiment station at Wooster was asked to test Sulfasan as a fungicide. Work done under the direction of Dr. H. C. Young developed the information that this material was highly fungicidal. Later testing showed it was so phytotoxic the possibility of using it as a herbicide was indicated. In 1944 preliminary tests demonstrated Sulfasan's ability to kill emerged weeds.

However no further work was done with Sulfasan until the winter of 1947. At the request of the Ohio Sugar beet growers a project was set up by the Ohio Agricultural Experiment Station to control weeds at the pre-emergence stage. Sulfasan was tested in the greenhouse early in 1948 along with other known and prospective herbicides. Sulfasan was outstanding from a safety-to-the-beets standpoint and gave satisfactory control of the weeds. Field tests at Old Fort, Ohio in 1948 confirmed the preliminary work.

From this work and several hundred other plot tests last year, it was further indicated that Sulfasan has a definite place in the pre-emergence control of weeds in row crops. Commercial work on corn and potatoes developed important information. On river bottom soil where corn has always been hand weeded, acre plots were set up and sprayed with a Myers side delivery air blast sprayer. The application of Sulfasan was made when the corn was just starting to break through. The results of the test follow.

Corn planted June 3—Pre-emergence sprayed, June 8. Soil—dry with few weeds showing and those only in low spots. Width of plots 60, area, 1 acre. Herbicides applied from sides of plots in a 30' swath. The acre check plots were hand weeded at a cost of $15.00 per acre and all plots were cultivated three times. The retail cost of the Sulfasan was approximately $12.00 per acre. Weed control was evident in the Sulfasan plots all through the season. The average yield of these plots exceeded the average of the check plots by 11 per cent.

On this farm potatoes are always hand weeded, but acre plots on which Sulfasan was applied before the potatoes emerged not only were not hand weeded but the cultivation schedule was cut to one combined cultivation and hilling operation. Average yield from these plots exceeded the checks by 14 per cent.

In 1949 yields were checked on peas, snap beans, soy beans, lima beans and sweet corn.

Peas pre-emergence sprayed and not cultivated out produced unsprayed but cultivated by 31 per cent. The unsprayed, uncultivated plots produced no marketable peas.

Snap beans pre-emergence sprayed and not cultivated produced 19 per cent more beans than the unsprayed but cultivated plots.

The unsprayed soy beans were a total loss, for weed growth was so heavy the whole area was plowed down.

Lima beans that were sprayed pre-emergence and not cultivated, out-produced the unsprayed-cultvated and hand weeded checks by 9 per cent.

Sweet corn sprayed pre-emergence out-yielded the unsprayed checks by 14 per cent. Both were cultivated twice. Weeds were absent at frost in the sprayed plots.

The use of Sulfasan for the pre-emergence control of weeds in row crops is a simple operation.

The soil is prepared in the usual manner and the crop planted. It doesn't seem to make any difference what crop. Then 24 to 48 hours before the crop emerges apply 2 gallons of Sulfasan emulsified in 50 gallons of water to the acre. Any equipment that will apply that gallonage with reasonable uniformity can be used. Pressures ranging from twenty to two or three hundred pounds can be used. If the equip-

ment will handle 100 or 200 gallons per acre better than 50 gallons, use that quantity. It is only necessary to see that 2 gallons of Sulfasan are applied to the acre.

The crop emerges, but the weeds don't. this statement should be qualified for if the weeds are perennials with a well established root system, like Canadian Thistle, for example, they may not be killed by a pre-emergence treatment.

There is an exception among the annuals too that we have encounted and there may be more—giant rag weed. We've found this plant growing from seeds that germinated 8" and more below the surface. The shoot is so large that it pushes the surface of the soil up and emerges through the crack. If this plant has emerged even as little as 1/16 inch at the time the herbicide is applied it is usually killed.

Soil type and structure do not seem to affect the performance of Sulfasan. Weather conditions likewise seem to have no influence. Applications have been made to dry soils in weather that continued dry and to wet soils even during rains with equally satisfactory results. Good weed control has been obtained in soils ranging from heavy-upland clays to light bottom land sands and mucks. Safety to crop is one of Sulfasan's outstanding properties. Tests with 4 gallons of Sulfasan to the acre, twice the recommended or necessary dosages, showed no crop injury. At 10 gallons, 5 times the recommended application, corn showed some early injury but outgrew such injury in two weeks. Soya beans and cabbage were not affected by this high dosage.

Lettuce and mixed grass seed scattered on the surface and lightly covered with 1/16" of soil and sprayed with 2 gallons of Sulfasan in 50 gallons of water to the acre produced a normal weed free stand.

The field work this year confirms the work done in 1948. Commercial tests were carried out this year on plots as large as ten acres with weed control and crop performance the same as on the smaller plots.

CONCLUSIONS

The results of two years work on a thousand or more plots as well as extensive commercial usage strongly indicate that the application of 2 gallons of Sulfasan emulsified in 50 gallons of water to the acre applied to row crops 24-48 hours before the break through gives excellent weed control with complete safety to the crop.

Wherever hand weeding is a part of the regular schedule it can likely be replaced by chemical weeding at a considerable saving.

Increased yields often result from the elimination of weeds when the crop is small. Often, season long weed control results from a single application at the pre-emergence stage.

Sulfasan possesses a greater factor of safety for the crop than the other chemicals that have been used in the investigational work.

Pre- and Post-Emergence Weed Control with Vegetable Crops 1947-1949

E. K. Alban and Leslie McCombs

Within the last few years the general subject of chemical weed control with vegetable crops has received the attention of many investigators. The number of chemicals available for study and the number of vegetable crops coupled with the variation in soils, varieties, concentrations of chemicals, environment and other factors has, however, produced somewhat variable results.

In this paper we have attempted to summarize our evaluation of the herbicides in regard to the vegetable crops studied under Ohio conditions. Those results cover the 1947, 1948 and 1949 seasons. However, not all of the chemicals or vegetable crops included were studied each season.

Some of the general aspects of these studies are included as well as a tabular presentation of results.

Major Weeds: present in most of these studies include: Purslane (Portulaca oleracea), rough pigweed (Amaranthus retroflexus), galinsoga Galinsoga parviflora), foxtail (Chaetochloa viridis), crabgrass (Syntherisma sanguinale), and Canada thistle (Cirsium arvense) in the asparagus planting.

Soils: Miani and Brookston Loam, and old and new muck.

Irrigation: Supplemental water was used on the heavy soils as needed to prevent crusting and also to study leaching of chemical; no irrigation was possible on the muck soils.

Spray equipment: Three gallon metal sprayers, compressed air type, with pressure guage and pressure control valve, and equipped with a special hand-boom with "Tee-jet" nozzles were used. Nozzles were interchangeable from 5 to 100 gallons per acre.

Application: Spray solutions were calibrated on basis of number of minutes to discharge a known volume of spray, under a uniform pressure, and with a given nozzle opening. The number of cubic centimeters of spray needed for any given plot size was determined and then the plot was covered in the number of minutes required to discharge that volume of spray. The nozzle opening was controlled so as to allow at least two and usually three trips over the plot. In this way a uniform coverage was obtained and the operator could walk at about a two- to three-mile-an-hour gait.

Yields: Yields were obtained with the following crops after pre- and post-emergence

treatment: Potato, sweet corn, onions, carrots, lima and snap beans. With most of these, records have been obtained for two years.

Stand and General Growth: All of the vegetables lited above as well as those in the following table have been studied on the basis of stand and general growth following pre- and post-emergence treatments for periods from three to ten weeks.

Varieties: While considerable difference has been noted between varieties of vegetables in regard to tolerance of a given chemical, the difference between kinds of vegetables is much more significant at the present time. With the exception of sweet corn and potato, our present knowledge would not indicate a change in chemical treatment on the basis of variety but rather on the kind of vegetable.

The following tables represent an attempt to summarize our experience with the chemical pre- and post-emergence treatments with vegetables, under conditions in Ohio as indicated.

TABLE I

SUMMARY OF PRE-EMERGENCE CHEMICAL WEED CONTROL STUDIES WITH VEGETABLE CROPS—1947-1949

Crop	Application* Time - Days after planting	General Evaluation of Chemical Treatments Studied Based on Weed Control and Crop Tolerance (1) PROMISING	INCONCLUSIVE	UNSATISFACTORY
Asparagus, plants	pre-sprout	1-4,7,8,10-14, 22,26,31,36,47	15,16,23-25,32, 38-46,48	5,6,9,17,18,27-30, 33,35
Asparagus,	10 to 15	1,2,10,11,36, 38	4	5,6,12
Bean, snap	5 to 7	19,20,46	13,14,30,31,35, 36,44,48	1,12,25-29,32-34, 37-43,45,47
Bean, lima	6 to 9	19,20,46	1,9,13,14,30,31, 35,36,38-40,44	2-8,10-12,25-29, 32-34,37-43,45,47
Bean, Mung	.....	.....	1,9,44,46	2-8,10-12
Beet	.....	.....	17-19,29-31, 34-36,38-40	1-16,20-28,32,33, 37,41-48
Broccoli	.....	.....	25-27,34-36,	1-16,19-24,38-40
Brussels sprouts	.....	.....	25-27	1-16, 38-40
Cabbage	.....	.....	25-27	1-16, 38-40
Carrot	8 to 11	38-40	17-19,29-31, 34-36	1-16,20-28,32,33, 37,41-48
Cauliflower	.....	.....	25-27	1-16,38-40
Corn, sweet	3 to 5	1-3,7-11, 18-22	14,15,21-23,35, 36,44,46	4,5,6,12,13,16,17, 24-34,37-43, 45,48

*Application time refers to best time for treatments listed under "PROMISING".
(1) Treatment numbers, and pounds of actual chemical used per acre.

1. 2,4-D ester	0.5	17. PCP	2.0	33. Xanthogen disulfide	5.0
2. 2,4-D ester	1.0	18. PCP	6.0	34. Xanthogen disulfide	10.0
3. 2,4-D ester	1.5	19. PCP	8.0	35. Xanthogen disulfide	15.0
4. 2,4-D ester	2.0	20. PCP	10.0	36. Xanthogen disulfide	25.0
5. 2,4-D ester	3.0	21. PCP	16.0	37. Xanthogen disulfide	50.0
6. 2,4-D ester	4.0	22. PCP	20.0	38. Aromatic oil (10-16%)	50.0 Gal.
7. 2,4-D amine	1.0	23. PCP	24.0	39. Aromatic oil (10-16%)	80.0
8. 2,4-D amine	2.0	24. PCP	32.0	40. Aromatic oil (10-16%)	100.0
9. 2,4-D Na salt	0.5	25. TCA	2.0	41. IPC	2.0
10. 2,4-D Na salt	1.0	26. TCA	4.0	42. IPC	4.0
11. 2,4-D Na salt	2.0	27. TCA	8.0	43. IPC	8.0
12. 2,4-D Na salt	4.0	28. KCNO	4.0	44. DNOSBP	5.0
13. NaPCP	7.2	29. KCNO	6.0	45. DNOSBP	15.0
14. NaPCP	10.8	30. KCNO	8.0	46. ADNOSBP	5.0
15. NaPCP	14.4	31. KCNO	12.0	47. ADNOSBP	10.0
16. NaPCP	28.8	32. KCNO	16.0	48. TADNOSBP	5.0

All 2,4-D sprays were applied at from 20 to 25 gallons, total spray per acre.
All other sprays were applied at from 40 to 50 gallons, total spray per acre.
Aromatic oil applied undiluted, as indicated.
See Key (page 4) for description of abbreviated materials and source.

TABLE I (Continued)

SUMMARY OF PRE-EMERGENCE CHEMICAL WEED CONTROL STUDIES WITH VEGETABLE CROPS—1947-49

Crop	Application* time - days after planting	General Evaluation of Chemical Treatments studied Based on Weed Control and Crop Tolerance (1) PROMISING	INCONCLUSIVE	UNSATISFACTORY
Cucumber	5 to 7	38 - 40	1,9,17-20,30,31,34, 44, 46, 48	2-8, 10-16, 21-29, 33, 41-43, 45, 47
Endive	6 to 8	38 - 40	.....	1-12
Lettuce, head	6 to 7	38 - 40, 30, 31	34, 35, 17-19	1-16, 20-29, 41-48
Lettuce, leaf	.....	.....	17-19,30,31,34, 35,38-40	1-16, 20-29, 32, 33, 41-48
Muskmelon	5 to 7	38 - 40	1,9,17-20,30,31, 34,44,46,48	2-8, 10-16, 21-29, 33, 41-43, 45, 47
Onion	8 to 11	18-20,35,36,38-40	1,9,13,14,30, 31,32	2-8, 10-12, 15-17, 21-29, 34, 37, 41-48
Parsnip	9 to 12	38 - 40	.....	1-12
Peas	.....	.....	1, 9	2-8, 10-12, 38-40
Potato	10 to 14	1-4,10-12,20,22,36 37, 38, 40	13, 15, 44, 47	9, 18, 19, 33-35, 38
Radish	3 to 4	14, 19, 26, 36	20, 21, 31	1-13, 22-25, 27-30, 32-35, 37-48
Spinach	7 to 9	19, 31, 36, 38-40	13, 14, 34, 35	1-12, 15-18, 20-30, 32, 33, 41-48
Tomato	7 to 9	19,31,32,35,36, 38-40	20-23, 46	1-18, 24-30, 33, 34, 37, 41-45, 47, 48
Turnip	.....	.....	19,20,26,31,35,36	1-18, 23-25, 27-30, 32-34, 37-43

*Application time refers to best time for treatments listed under "PROMISING".

(1) Treatment numbers and pounds of actual chemical used per acre.

1. 2,4-D ester	0.5	17. FCP	2.0	33. Xanthogen disulfide	5.0
2. 2,4-D ester	1.0	18. FCP	6.0	34. Xanthogen disulfide	10.0
3. 2,4-D ester	1.5	19. FCP	8.0	35. Xanthogen disulfide	15.0
4. 2,4-D ester	2.0	20. FCP	10.0	36. Xanthogen disulfide	25.0
5. 2,4-D ester	3.0	21. FCP	16.0	37. Xanthogen disulfide	50.0
6. 2,4-D ester	4.0	22. FCP	20.0	38. Aromatic oil (10-16%) Gal.	50.0
7. 2,4-D amine	1.0	23. FCP	24.0	39. Aromatic oil (10-16%) Gal.	80.0
8. 2,4-D amine	2.0	24. FCP	32.0	40. Aromatic oil (10-16%) Gal.	100.0
9. 2,4-D Na salt	0.5	25. TCA	2.0	41. IPC	2.0
10. 2,4-D Na salt	1.0	26. TCA	4.0	42. IPC	4.0
11. 2,4-D Na salt	2.0	27. TCA	8.0	43. IPC	8.0
12. 2,4-D Na salt	4.0	28. KCNO	4.0	44. DNOSBP	5.0
13. NaPCP	7.2	29. KCNO	6.0	45. DNOSBP	15.0
14. NaPCP	10.8	30. KCNO	8.0	46. ADNOSBP	5.0
15. NaPCP	14.4	31. KCNO	12.0	47. ADNOSBP	10.0
16. NaPCP	28.8	32. KCNO	16.0	48. TADNOSBP	5.0

TABLE II

SUMMARY OF POST-EMERGENCE CHEMICAL WEED CONTROL STUDIES WITH VEGETABLE CROPS—1947-49

Crop	General Evaluation of Chemical Treatments Studied Based on Weed Control and Crop Tolerance (1) PROMISING	INCONCLUSIVE	UNSATISFACTORY
Asparagus (a)	4,5,9,10,14,17-19, 21-23,26-29,38	11, 15, 24, 30, 31-37, 42	1-3, 6-8, 12, 13, 16, 20, 25
Carrot (b)	3, 4, 5	.....	1, 2
Celery	.....	3	1
Sweet corn (c)	7-9, 13, 14	10, 15	1-6, 11, 12
Onion	.....	16-18, 20, 21 39, 40	1-15, 19, 23-30
Peas	.....	40	.....
Potato	.....	7, 8, 12, 13	6, 9-11, 14, 15

(1) Treatment numbers, kind and rate per acre of chemical. Pounds, except as noted.

1. Aromatic oil	25	gallons	16. KCNO	4.0		31. IPC	2.0	
2. Aromatic oil	40	"	17. KCNO	8.0		32. IPC	4.0	
3. Aromatic oil	50	"	18. KCNO	12.0		33. IPC	8.0	
4. Aromatic oil	80	"	19. KCNO	16.0		34. TCA	2.0	
5. Aromatic oil	100	"	20. NaPCP	3.6		35. TCA	4.0	
6. 2,4-D ester		0.125	21. NaPCP	7.2		36. TCA	8.0	
7. 2,4-D ester		0.25	22. NaPCP	10.8		37. Xanthogen disulfide	15.0	
8. 2,4-D ester		0.33	23. NaPCP	14.4		38. Xanthogen disulfide	25.0	
9. 2,4-D ester		0.50	24. NaPCP	21.6		39. ADNOSBP	1.0	
10. 2,4-D ester		1.00	25. PCP	6.0		40. ADNOSBP	3.0	
11. 2,4-D ester		2.00	26. PCP	8.0		41. ADNOSBP	5.0	
12. 2,4-D sodium salt		0.25	27. PCP	10.0		42. Aero-cyanamid	100-lbs.	dust
13. 2,4-D sodium salt		0.50	28. PCP	16.0		Defoliant Grade		
14. 2,4-D sodium salt		1.00	29. PCP	20.0				
15. 2,4-D sodium salt		2.00	30. PCP	24.0				

All 2,4-D treatments were applied in water at 20 gallons per acre. All other treatments except those noted were applied in water at a 50-gallon total solution peracre.

Time of Application, Refers to Treatments Listed under "PROMISING"

(a) Asparagus: At the end of the cutting season and approximately two to six weeks after discing. The plants were allowed to grow to a height of two to three feet, before applying the sprays. All sprays were directed at the base of the plant. Extreme care was necessary to avoid drift to softer foliage.

(b) Carrot: Spraying started as soon as plants reached two to three-leaf stage and continued until approximately six weeks before harvest as needed. Best results obtained where only one or two early sprays were applied and regular cultivation was maintained.

(c) Sweet corn: Best results have been obtained when sprays were applied from time of emergence of corn up until about an 8- to 10-inch plant has developed. Temperature and rate of growth of plant are more important than height. Spray should be directed so as to hit weeds with minimum spray striking upper foliage of corn plant.

The following is a list of the chemicals studied with the abbreviations as used in Tables I and II, as well as the source of these chemicals. All of the companies listed supplied the chemicals for testing purposes without charge. In addition The Sherwin-Williams Co., Dow Chemical Co.; Shell-Oil Co.; and the Monsanto Chemical Co., supplied funds through Grants-in-Aid in carrying out certain phases of these studies.

2,4-D ester, supplied by The Dow Chemical Co., and The Sherwin-Williams Co.

2,4-D amine salt, supplied by the Dow Chemical Co.

2,4-D sodium salt, supplied by The Dow Chemical Co.

NaPCP, sodium penta-chlorophenate, supplied by The Dow Chemical Co., and The Monsanto Chemical Co.

PCP, penta-chlorophenol, supplied by The Dow Chemical Co., and The Shell Oil Co. The PCP from Dow Chemical was mixed with Diesel Fuel No. 1 before mixing with water.

TCA, tri-chloroacetate (Sodium salt), supplied by The Dow Chemical Co.

KCNO, potassium cyanate, supplied by The American Cyanamid Co. Also Cyanamid, devoliant grade supplied by the American Cyanamid Co.

Xanthogen disulfide, supplied by The Monsanto Chemical Co., and The Sherwin-Williams Co.

Aromatic oil (10 to 16%), supplied by The Standard Oil of Ohio, and The Shell Oil Co.

IPC, isopropyl N phenyl carbamate, supplied by The Dow Chemical Co.

DNOSBP, di-nitro ortho-sec butylphenol, supplied by The Dow Chemical Company.
The Dow Chemical Company

ADNOSBP, Ammonium dinitro ortho-sec butylphenate, supplied by The Dow Chemical Co.

TADNOSBP, Tri-ethanoleamine dinitro-o-sec, butylphenate, supplied by The Dow Chemical Co.

GENERAL SUMMARY BY CHEMICAL

A. 2,4-Dichlorophenoxyacetic Acid

Form: Pound for pound under Ohio conditions, the ester formulations are more effective than the amine or sodium salt formulations. Under ideal moisture, temperature, and soil conditions, as indicated by greenhouse studies, there is very little difference between the ester and sodium salt forms.

Field applications over three years indicate that usually ester formulations can be reduced one-third to one-half of recommended concentrations of sodium salt based on acid equivalent.

Ester formulations are likely to drift further than salt formulations, when spraying, due to smaller particle size of spray. Volatility of ester forms from soil or plants after spraying has never been of any consequence on the small plots used. However, when comparatively large areas have been sprayed, there has been scome indications of volatile damage to adjacent susceptible crops.

Vegetable Crop Use: At the present time 2,4-D appears to be most useful as a pre-emergence spray on sweet corn, potatoes, and asparagus. It is also important as an early post-emergence treatment on sweet corn. As-

paragus has also been successfully treated for three years, when spray has been directed at base of plant and on weeds. The upper foliage of asparagus is severely damaged when sprayed with 2,4-D.

Weeds: Excellent control of most annual broadleaf weeds has been obtained with one to two pounds of 2,4-D acid equivalent as pre-emergence treatment. Excellent control of crabgrass and foxtail has likewise been obtained at the above rates when chemical was applied to soil about two days prior to emergence of the grass seedlings.

Good to excellent results have been obtained when spraying one-fourth to one pound of 2,4-D acid equivalent on annual broadleaf weeds during early period of growth. Weeds up to two or three inches tall are much easier to kill than larger weeds. Practically no control of crabgrass and foxtail has been achieved by spraying after emergence of these two grasses.

Residual: 2,4-D must be handled with extreme care in areas where a wide range of vegetables are grown. There is a problem not only of soil residue which may vary from two weeks to a year, but also of residue on workers' shoes, equipment, non-weathered compost soils, storage buildings, and many others. Field soils treated with 2,4-D will lose most of the toxic residue of a one to two-pound application within six to ten weeks with average rainfall (Ohio).

B. Sodium pentachlorophenate

Vegetable Crop Use: Pre-emergence application of NaPCP appears to hold some promise for such crops as radish, potato, spinach, asparagus, and sweet corn of the crops studied. Further studies are required before any real measure of its value is possible. Post-emergence application on onions has shown variable results but work should be continued.

Weeds: Excellent pre-emergence and post-emergence control of annual broadleaf and grass weeds has been obtained with NaPCP.

Residual: Residual effects of NaPCP have been noted on muck soils for as long as twelve weeks when only 7.2 pounds of actual NaPCP were applied per acre.

C. Pentachlorophenol

Vegetable Crop Use: This material appears to be promising as a pre-emergence treatment on such crops as snap and lima beans, sweet corn, onion, potato, spinach and direct seeded tomatoes.

Weeds: The material has both contact and residual effects on weeds. However, the best control of annual broadleaf and grass weeds has been obtained with a delayed pre-emergence treatment. In studies where PCP was applied at time of planting and one, three and five days after planting to separate plots, the three-day after planting treatments always produced better weed control than 0, 1, or 5-day treatments. This same effect has been noted with DNOSBP and TADNOSBP. Residual effects not accurately determined in our studies to date.

D. Tri-chloroacetate, sodium salt

Most crop plants were damaged with TCA used as a pre-emergence treatment. The notable exception was the apparent tolerance of the Cruciferous crops to the rates applied. Definite residual effects were apparent but time factor has not been determined.

E. Isopropyl N phenylcarbamate

This chemical has been difficult to work with either as a wettable powder or as an emulsion. The major value of this material as noted in our studies was the exceptionally good control of purslane in all plots treated. Some residual effects noted on weeds and crops.

F. Potassium cyanate

This chemical was studied primarily as a post-emergence herbicide for onions. The results were not satisfactory in most instances but further work is needed. This material was also used in pre-emergence studies and it does appear to have considerable value in controlling small annual weeds before the crop emerges without any problem of residual effect in soil. The higher rates of KCNO also appeared to be valuable in controlling annual weeds in asparagus during the cutting and post-cutting season.

G. Xanthogen disulfide

This chemical was used primarily in pre-emergence studies and appeared to have some value as a contact spray with very slight residual effects. The spray must be applied before the crop plant emerges. Broadleaf weeds have been controlled rather well at the higher rates but the grass weeds in general are not adequately controlled.

H. Aromatic Oil (10 to 16%)

The successful weeding of carrots and

certain other Umbelliferae with aromatic oil is generally accepted as a standard practice. The use of these oils in pre-emergence application is limited to those slow-germinating crops which allow some weed emergence before crop emergence.

I. Dinitros

The three dinitro compounds included in this report have not received sufficient study to attempt to clearly evaluate them. Our results with the three materials have pretty nearly paralleled those listed under C (pentachlorophenols). In general, the dinitro compounds have reduced the stands of vegetables more than pentachlorophenols in pre-emergence studies.

Taking Stock of Weed Research

R. M. Salter

Technical papers on weed research are the order of the day at this weed conference. They were yesterday. They were today. And they will be again tomorrow. But not tonight—because I cannot claim distinction as a weed specialist.

My remarks will be directed toward a general stock-taking in weed research, I will review the progress to date, discuss the direction of weed research generally, and announce plans for a new Weed Division in the Bureau of Plant Industry, Soils, and Agricultural Engineering.

Fifteen years ago weed research was practically nonexistent in this country except in a small way at a few State stations. In 1934 there were only three men in the entire United States devoting their full effort to weed research. Generally speaking, weed control measures in use on farms were the same as they had been for a thousand years—just plain all round good farming.

Unfortunately, many who worked the land had not done a good job of farming. Some weeds were getting out of hand, especially perennial weeds like bindweed in the Midwest. It was apparent that for the degree of infestation reached on many farms even what were then considered good farming practices conld not correct the condition.

The Congress recognized this and directed the Bureau of Plant Industry, with an accompanying appropriation of funds, to investigate the problem. Consequently, a weed project was set up in the Bureau in 1935 for the specific purpose of investigating bindweed in cooperation with State experiment stations. Since then cultural methods, including cropping and intensive cultivation, have been devised that make it possible for any farmer anywhere to keep bindweed under control.

Investigations with Russian Knapweed, whitetop, butgrass, and weeds on irrigated lands in the western United States have been added to the project in recent years. And even more recently there has been opportunity to do even more general work through added support from Research and Marketing Act funds. Good progress is being made. We must admit, however, that while most satisfactory in many ways, it is too slow considering the magnitude of the losses from weeds.

Most State experiment stations, too, have initiated or rejuvenated weed projects since 1935. An abundance of worth-while information has come out of this work. In most States the extension service has inaugerated vigorous programs for disseminating the new information. Several State legislatures have enacted weed control laws based on the research findings. Many important advancements have been made in weed control during the past 15 years.

A turning point in weed research came about seven years ago when several investigators, including Kraus and Mitchell in our Bureau, found that plant growth regulating chemicals could be used for killing weeds selectively. This discovery opened the door to new opportunities for controlling annual weeds on crop land. It directed new emphasis toward a different approach to this old, old problem.

Since 1945, weed projects have mushroomed all over the country. In the short span of four years the working force of weed specialists in this country has grown from a mere handful to numbers more proportionate to the job. People generally are becoming weed conscious. The tremendous cost of the weed menace in agriculture is being brought into sharp focus. Farmers as a group know more about weed control today than the specialists knew 15 years ago. They are, however, clamoring for definite answers to their specific problems.

The information that will at least partly answer the farmer's problems is being turned out in tremendous volume, but in many cases application has gotten ahead of research. Developments come so fast, both in new chemicals and methods for their use, that it has become difficult even for those who are specialists to keep up with the findings of their fellow scientists. So, gatherings of this kind are held to exchange knowledge. The great interest in this weed control conference—and the three other regional conferences held each year—is ample evidence of the need for even more intensive weed investigations.

Changes in emphasis and approach have been so rapid, I think it worth our time to discuss the direction of weed research generally. What I have to offer along this line is not new, but it is vital in any stock-taking process.

Adequate systems of farming, which include those measures of soil management and cropping necessary for sustained production, will usually go a long way toward controlling weeds and at the same time offer greater potentiality for increasing the efficiency with which farmers grow crops than any other measures that can be taken. This could never be forgotten in viewing the weed problem in terms of modern technology.

When a farmer has built up his soil to a high level of fertility, has prepared a good seed bed, has planted good seed of an improved variety—and has prayed for rain—he is all set to make a big crop. The measures he has taken, in themselves, will help to prevent

weeds. Of course, such uncontrollable factors as unfavorable weather, which may prevent a good stand, can create a serious annual weed problem even then, and inadequate control may well cut out a farmer's profit. Or, if the cost of control is too great, it may eat up his profit. An important objective of all weed research, therefore, must be to develop methods for controlling weeds effectively at the least possible cost.

Farmers already have reasonably satisfactory methods for controlling weeds in many cultivated crops. Mechanical and hand methods are generally reliable, except during periods of unusual weather when they may break down. Recent research findings have turned out new methods that often can be used to fill in under these conditions. For example, 2,4-D performed nobly as an emergency measure in the winter wheat area in the spring of 1948. Annual weeds would have taken over on many wheat fields that spring because of poor stands had farmers not had 2,4-D to come to their rescue. Corn growers in several areas have had similar experiences in recent years.

While most of us know some methods that are reasonably reliable, they may not stand up so well when judged from the standpoint of cost and efficiency. These factors become increasingly important when crop prices are declining. The cost of weed control is a major item in total cost of crop production on most farms today. To reduce that cost is a major challenge to all concerned with modern weed research. In some instances it may be possible to improve present methods and make them more efficient. In other instances it may be necessary to develop entirely new methods that are less costly.

In any event it is obvious that preventing weeds is cheaper than controlling them. Research on weed prevention is not receiving sufficient attention. I realize that this line of endeavor is unspectacular and lacks the glamour of some of our newer techniques, but it offers opportunities that should not be overlooked.

Many opportunities still exist for saving seed from crop plants without gathering weed seeds, for cleaning weed seeds from crop seed stocks, and for destroying the viability of weed seeds in mixed feeds that have not been fully explored. You who are concerned with weed control must never forget that unless you take an interest in State weed laws—and in their enforcement—you will be wasting much of your time.

There are other methods of weed prevention, too. We know that thistles and bindweed are easier to control when legumes and grass crops are used in the rotation. Cockleburs are controlled on many Corn Belt farms with one or two years of oats in the rotation. There are many such examples, yet I doubt that we have capitalized fully on the advantages of good farming and the best combinations of crop sequences that will help to ease the weed problem. Measures for weed prevention should receive considerable emphasis in a well-balanced weed research program.

We should raise some questions about the place of chemicals in weed control. Chemical weed control methods are here to stay without question. In fact, chemicals will undoubtedly play an ever increasing role in weed control programs. The question is whether we are permitting research with chemicals to overshadow research with other control methods.

It is my considered opinion that from the standpoint of a well-balanced weed research program the chemical aspect is being over-emphasized. We must never lose sight of the fact that there is no panacea for weed control, and chemicals cannot be considered a means to avoid all other weed control measures. If the farming job is done right, chemicals may not be needed. If a particular weed control job may be done more efficiently by some other method, it is our responsibility to explore the possibilities. Furthermore, many farmers have been willing to adopt chemical methods during a period of relative prosperity in the agricultural economy. During periods of declining agricultural prices we can anticipate an ever increasing tendancy for farmers to fall back on weed control methods that do not call for a cash outlay for materials. Those in charge of weed research should be prepared with improved methods that, although less spectacular, will be equally satisfactory in a period of lower agricultural income.

The principle of combining several practices into one operation appears to offer tremendous opportunity for reducing farm operating costs. One can imagine all kinds of combinations that might be investigated. 2,4-D mixed into lawn fertilizers does a satisfactory job of combining weed control with the application of plant nutrients. Its main drawback at present is the high cost of the mixed materials. Initial results from using one application of calcium cyanamid for two jobs—pre-emergence weed control and as a source of nitrogen fertilizer— appear sufficiently encouraging to warrant more intensive investigations.

You are familiar with attempts to develop dual-purpose chemicals that will kill both weeds and insects in one application. Who knows whether that might some day be worked out successfully? We often hesitate to spray or dust field crops for insects or disease control because the cost of application is high in comparison with the moderate yield increases that can be expected. If such applications could be combined with another operation so that both could be done simultaneously, then more insect and disease control measures might become economically practical.

In the South several investigators are experimenting with combinations of practices in cotton production. One three-way operation includes cultivating between the row and spraying or flaming in the row for weed control and spraying for insect control—all in a single trip with a tractor. Another combination includes apparatus mounted on a tractor to apply liquid ammonia, plant cotton seed, and spray with a herbicide all in one operation.

Other attempts, too, are being made to combine practices. If techniques can be worked out for successfully combining the application of two or more practices on a given field, they could make a substantial contribution toward reducing the operating cost on that field. Furthermore, they may offer an added advantage in terms of soil structure. There is good evidence that unnecessary tillage and traversing the land with heavy equipment should be avoided whenever possible.

Some people are concerned about our improved methods becoming too complex and complicated for farmers to use. It is true that the advantage of many new techniques rests with accuracy and precision in their use. This does not make them impractical provided the farmer is given precise instructions regarding their use and understands the necessity for following those instructions.

Using 2,4-D to control annual weeds in small grain or corn offers an example. Basically the chemical is relatively simple to use. The problem begins to get complex when you consider all the ifs, ands, and buts that are thrown in as qualifications. Many of these qualifications arise from the fact that there is such a multiplicity of commercial formulations that vary only slightly in an extra added ingredient included by the manufacturer to make his product different and, he hopes, more saleable. There are also certain unavoidable complications, such as variations in soil, climate, and crop variety reactions. These can all be minimized and the recommendations simplified as we develop more complete knowledge through experimentation.

While on the subject of chemicals there is another point that should be mentioned. The potentials from growth regulating substances are so dramatic that advantages of other chemicals, such as petroleum products, are not being fully explored. If given more thorough investigation, other chemicals may prove to be as important as the so-called hormone chemicals in effective economical weed control.

Intensive work is needed in the engineering field of weed control, too, despite the good progress of recent years. The development of low-volume high-pressure spray rigs has contributed immensely to the practical application of new herbicides. There is still room, however, for other advancements that will further simplify the application of chemicals and insure a more even spread of materials. Generally speaking, the machines being used for the application of chemicals were originally designed for some other purpose and have been adapted to this new use. Farmers are asking for a new light-weight all-purpose ground spray rig that can perform all the various spray jobs on a given farm.

Airplanes, too, which are becoming increasingly important as an agricultural tool, were designed for other purposes and have been adapted for farm spraying. Our Bureau, the Texas Experiment Station, and the Civil Aeronautics Authority are now cooperatively studying the possibilities of designing a new type of airplane to fit the specific needs for applying materials for farm crops from the air.

I would like to comment briefly on the balance between fundamental research and applied studies in the field of weed investigations. With the rapid advances in certain fields of weed control during recent years, application has gone far beyond research. At the present time the two are seriously out of balance.

Much still remains to be learned about fundamental effects of many new chemicals on plants. We still don't fully understand the physiological change brought about in a plant by some chemicals that result in plant death. Why do some species of plants react differently from other species when certain chemicals are applied? Why do the reactions differ among some plant varieties in the same species? When answers to these and other questions are found, perhaps recommendations for the application of these chemicals can be simplified and made more accurate.

The importance of fundamental science has been illustrated over and over in our time. Without an enormous amount of fundamental study in the field of physics the atomic bomb would have been impossible. Penicillen, sulfa, and the other new wonder drugs are the products of fundamental research in medical science. Selective weed killers came out of fundamental studies with plant hormones in our own field.

Many people have the impression that all fundamental investigations are highly technical and separate and distict from applied studies. That is a false impression that must be corrected. Fundamental research may be complex or it may be simple. It is fundamental so long as it is designed to reveal what causes what and how it does it. Many of our applied studies in weed investigations could and should include fundamental investigations of an interpretive character.

Neither you nor I would attempt to predict what new discoveries might grow out of intensive fundamental research with weeds. We can be certain, however, that unless fundamental and applied studies are brought into better balance in the immediate future, applied studies will suffer. It is common knowledge that if a milk cow is to refreshen, preparatory action must be taken well in advance of the freshening period. In science the shut-off period is not as immediate and definite as with a milk cow, but it is almost as certain in the long run. Yet, it is dificult to convince those in charge of the purse strings of the necessity for preparatory action in weed control.

There are numerous lines of work that deserve intensive investigation. I have already referred to several, but many more might be mentioned. We actually know very little about biological methods for controlling weeds. The use of insects to control Klamath Weed in California shows promise, and there may be a possibility of controlling gorse with seed infecting insects. Other attempts to use biological methods in this country have been unsuccessful. Yet, the Australians are using insects to eradicate prickly pear. We don't know whether this method would work on our Southwest range land. Before trying it, considerable basic study would be necessary to be sure that the insect would not also destroy any valuable economic plants. If this method should be found effective and safe, it still would be difficult to convince some ranchers of the desirability of using the method until agronomists develop a substitute feed for drought periods.

Although, in the light of our present admittedly scanty information, controlling weeds through biological methods seems to offer little opportunity for wide scale practical application in the immediate future, biological studies should most certainly be included in a long-range weed research program.

We are also lacking in knowledge about the interrelationships of weeds, insects, and plant diseases. Several plant diseases have been found to be associated in one way or another with weed problems.

You are familiar with the inter-relationships of barberry and wheat stem rust. There are several similar examples. In Florida weeds serve as an intermediary host in a disease of celery. The leaf roll virus of potatoes is transmitted by insect vectors that may over-winter in weeds adjoining potato fields. Weeds play a key role as a reservoir of the curly top virus that affects sugar beets and other crops. We need more information generally about the inter-relationships of various weeds, insects, and plant diseases.

And there are specific problems, too, for which satisfactory answers have not been found, such as the control or eradication of noxious woody plants. Despite the advances with new chemicals in recent years, much of the brush problem remains unsolved. Brush constitutes a problem in varying degrees in almost every section of the country. All over the United States extensive areas of farm pasture are low in production because of brush.

The re-occurring cost of keeping trees and brush cleared from telephone and electric line right-of-ways is tremendous. There is serious need for the development of lower cost methods for maintaining the right-of-ways for the millions of miles of lines that carry electric power and communication facilities to farm families of the nation.

There are scattered areas all over the country where brush-infested land is being held out of cultivation because of excessive clearing costs. If low-cost clearing methods could be devised, considerable additional land could be made to contribute to the general welfare of the nation.

The brush problem is most spectacular in the Southwest range country where at least 100 million acres of formerly productive range, grass land are now infested with mesquite, live-oak, shinnery oak, cedar, prickly pear, sagebrush, white-brush, blackbrush, and many other kinds of noxious woody plants. I spent a week traveling through that brush area early this fall. It is difficult to appreciate the seriousness of the problem without seeing it first hand.

The brush is often so thick you can't see a herd of cattle 100 yards away. It is costing stockmen millions of dollars annually. The carrying capacity of the range is falling off while operating costs are mounting. Every year hundreds of animals disappear in the brush, never to be seen again. Cowboys risk their lives searching the brush for cattle. Complete round-ups for dehorning, branding, vaccinating, and other treatments, are impossible. With hoof-and-mouth disease only a few hundred miles away in Mexico, brush has become a potential hazard for the entire livestock industry of the country.

Landowners are fighting back—and have been—but brush still has the upper hand. At least 150 million dollars have been spent in an effort to clear the brush menace from the Southwest range. The trouble is that present control methods are so costly that the dollars won't stretch over enough acres. Stockmen are asking for help in finding practical low-cost methods for killing the invaders.

The land that has become invaded with brush is low-cost land. Again weed investigators are challenged with the problem of finding effective control measures that can be applied economically. That in itself is a gigantic challenge but it encompasses only a portion of the problem. The advantages from brush eradication would be short lived without accompanying measures for revegetating the range and keeping pastures brush free and productive. All phases of the problem should be attacked simultaneously.

All the efforts that can be mustered under present research budgets are being directed toward that end. Progress is being made but the limitations of facilities and manpower are prohibiting work on the scale that is needed. The problem is of such tremendous proportion that solution will be most difficult until the full forces of agricultural science and the facilities of Federal, State, and commercial agencies can be brought to bear on it.

The aquatic weed problem also deserves mention, even here in the North Central region. Research with aquatic weeds will come more and more to your attention in the years ahead. With the development of the Missouri River Basin, and the general growing interest in supplemental irrigation, many of you in the not too distant future may face actual problems of weed control under irrigation that vary considerably from those with which you are now struggling.

These include not only new weed infestations brought into fields with irrigation water and the control of weeds on ditch banks but also control in irrigation canals, and in water reservoirs. Our study of these and other problems, underway in the West since 1946, have produced much information which we hope will result in successful control measures. Cooperative research with Army Engineers on control of water hyacinth in the Gulf Coastal area conducted by our Bureau for the War Department, has produced effective means of economically clearing that pest from navigable streams. Incidentally, control also increases the fish population and makes mosquito control possible.

The control measures developed through the research in the South and the West have generated considerable interest in extending research with aquatic weeds beyond the field of agriculture. A bill was introduced during the last session of Congress that would provide for research on methods for controlling aquatic weeds in water reservoirs, municipal water supply systems, and water recreation centers including both fresh water lakes and coastal resorts. That bill was still in committee when Congress adjourned in October.

We could go on for hours considering other specific weed problems and related research. I think it more important, however, to spend a few minutes discussing organization for weed research. It is the firm belief in our Bureau that the most progress can be made through cooperative research. Whether a State, Federal, or commercial agency helps in the work, is not important in the end result so long as the job is done.

Individually we do not have extensive resources for weed research. Collectively the resources are considerable even though some of us might still think them inadequate. As public servants, State and Federal employees certainly have an obligation to get the most in return from public funds. This can best be done by all working together. That is the policy un-

der which weed investigations in our Bureau have always been conducted and that is the policy under which future investigations will be carried out.

In most cooperative research there are certain phases of the work that each member of the cooperating group can best perform. The specific phases will vary with each problem, with the agencies concerned, the facilities available, the people involved, and the authority under which the operating funds are provided. Because of these many variables, generalizations are difficult. I will, however, outline in broad terms the responsibilities as we see them in our Bureau.

Broadly speaking there are two public agencies responsible for agricultural research—the State experiment stations and the U. S. Department of Agriculture. Although one is under State direction and the other under Federal direction, both operate on public funds. There is obligation to see that these funds are expended wisely without duplication. Defining responsibilities to avoid duplication offers one method for meeting that obligation. Working together offers another method. We feel that combining the two methods is best.

Although the work of State stations must be directed primarily toward the solution of weed problems that occur within the geographic boundaries of their respective States, findings in one State may be applicable to other States. An important function that the Department can perform is to assist the States in planning and coordinating such work, and in defining regional and national limitations of results. This can include help to assemble annual data accumulated by all cooperators, summarize the findings, and make them available to everyone concerned. Such a service can contribute materially to the progress of research and in preventing unnecessary duplications and misunderstandings of interpretation in the several cooperating States.

The responsibility of the Federal Government in cooperative research, however, should not end with this function alone. There are many weed problems of broad geographic significance that must be attacked regionally or nationally. In attacking these broad problems we believe that our Bureau can perform useful functions in helping to organize cooperative programs, in providing specialized competence or facilities for servicing regional programs, and in making interpretations for guiding regional and national action programs. It also is appropriate that Federal effort be directed to fundamental research that has wide application, although obviously this is a field in which the State stations and grade schools should contribute in a major way.

Since State funds for weed research have been increased generally during recent years, the time has come when Federal funds for weed research should be directed more toward problems that cross State boundary lines and less toward subsidizing research on strictly State problems. Certain kinds of broadly applicable research can be handled best at one specific geographic location in a cooperative program. While many States are interested, it would be inefficient for each to duplicate personnel, effort, equipment, and overhead expenses to attack the problem. In a cooperative program our Bureau can justifiably handle responsibilities of regional and national functions.

Federal participation in a cooperative project does not mean Federal domination of the research. Instead, it means a division of duties and responsibilities to which all agree. We firmly believe that leadership must be based on respect for the individual on the basis of his ability, his integrity, his fairness, and his willingness to consider the welfare of the work and the rights of other individuals above his own. That is the only kind of leadership under which cooperative work can be carried on successfully. In any specific instance, therefore, the most active leadership might rest with a State or with a Federal man, depending upon the circumstances.

Within the Federal Government weed control research is conducted by a number of different agencies. Each agency is interested only in certain phases of weed control. Other phases are often excluded from their work. This means that care must be exercised to assure a balanced program and to avoid unnecessary duplication and overlapping. An attempt is being made to do this, but due to the recent rapid expansion of weed research, the work is not yet as well coordinated as we hope for.

During the past few years many commercial companies have organized weed research programs. Most of this work is well planned and conducted by competent scientists and has contributed much useful information. The motive for research by commercial companies naturally dictates that investigations emphasize the products with which the company is commercially concerned. Such research can be most useful, particularly in developing new materials. It cannot, however, supplant State and Federal research. To be most effective in both commercial and public interest, it is desirable that there be friendly and understanding relations between commercial and public research agencies. This we are happy to say exists in most cases.

We are concerned, however, that commercial companies—currently able to pay high salaries—are continually hiring scientists away from research agencies. We recognize that, within certain limits, research agencies have served and will continue to serve as a training ground of personnel for commercial and other allied activities implementing the results of our work. We also recognize that the right of an individual to improve his financial status should not be over-looked. We feel, however, that there is an obligation to consider the importance of the research and its results, and not to pull men out under circumstances that virtually stop the work, or at best prevent its completion for some considerable time. In a field where qualified personnel are already limited, such circumstances react against all concerned. A little friendly joint consideration can usually provide a satisfactory arrangement. In some cases when our research personnel have been hired away we have been criticized because results have not been obtained more rapidly. We do not resent proper criticism, but it is disconcerting when the criticism is not understanding.

We in the Bureau of Plant Industry, Soils, and Agricultural Engineering are deeply concerned about the tremendous drain of the weed menace on agri-

culture and are anxious that research facilities be developed on a basis adequate to meet the research responsibilities involved. The research facilities of the Bureau are being reorganized to bring them into sharper focus on the weed problem generally. A new Division of Weed Investigations is being established. This division will be responsible for all weed work in the Bureau. Weed problems of all crops will be integrated under the direction of this unit. None will be neglected in so far as funds permit. Work on machinery for weed control will be coordinated with other weed research through the Weed Division. I am sure this action meets with your approval since from time to time you have asked for it. We told you that at the opportune time it would be done. This is the time.

Reorganization does not mean any immediate marked expansion in resources. It does emphasize, however that the importance and scope of weed research has progressed to a point where the interests of the program now can be handled most satisfactorily through a responsible organization on a par in all respects with other units handling functions similar in degree of importance.

Dr. Roy L. Lovvorn has been selected to head the new division. Many of you know Dr. Lovvorn and are acquainted with his experience and abilities—and his training and interest in plant physiology. This special interest, so important in weed research, together with his broad experience in crop management, can contribute significantly in the development of sound weed control investigations in a program where weed control is considered as only one phase of good crop production.

Since 1936 Dr. Lovvorn has been on the staff of the Agronomy Department at the North Carolina State College of Agriculture. For the past five years he has been responsible for the supervision and direction of the cooperative pasture management investigations between our Bureau and the North Carolina Station. He is well experienced in Federal-State cooperative research. He has carried out one of the best pasture management research programs in the United States. He has achieved excellent results in training men in scientific research. This is a good background for administering research and for developing research staff relationships.

It is our intention that the establishment of the weed research division will give the emphasis to study of this important problem that its seriousness merits. We will continue to do all we can to advance weed rpsearch programs and carry our share of the obligations. We are confident that we can count on your support for a national weed research program in which State, Federal, and commercial agencies will all participate cooperatively for the betterment of American agriculture.

Honoring Membership Presentation

R. S. Dunham

It would be a pleasure under any circumstances to award an Honoray Membership for this Conference. It is doubly pleasant, however, when this award can be made to an old friend. And Al Larson is an old friend of mine. I am tempted to say that I knew him before he knew any weeds but that would be an exaggeration. I've been told that Al knew the scientific names of 100 weed species when he graduated from kindergarten.

Some of us have become interested in weed control only since the 2,4-D revolution of 1945, some of us go back to Sinox, some of us remember the introductory use of sodium chlorate and the arsenicals, some of us began with only cultural methods. Mr. Larson's interest in weeds and their control goes back to 1917 when he joined the staff of the University of Minnesota as an Agricultural Botanist and organized a course in weeds. Ever since, he has been identified with weed work. If you were to conduct one of these psychological tests of association where you speak a word and your subject answers with the first word he thinks of and you were to say weeds, it would be a safe bet that anyone from Minnesota would immediately say Al Larson. Have you ever seen his office desk, tables, and chairs covered with plants for identification and letters asking for methods of control?

Frequently, Al is invited to teach Nature Study at a summer 4-H camp. No one could be more at home in this work. He really knows the out of doors. One of his teaching methods is to tell his group of youngsters to go into the woods and fields for an hour and gather plants. When they return to the camp site they are instructed to throw their collections onto a pile. Then Al gets on one side and the kids on the other and one by one he picks up a plant, names it, and tells some interesting facts about its life habit or peculiar characteristics.

Mr. Larson is not known primarily for research work. It is difficult for him to divide nature study into the precise categories of Project Statements and Budgets. But he has carried on an individual research over the years that has resulted in a fund of information which equips him for the task of teaching and advising that he so ably carries on.

I know of no one who better deserves a citation in recognition of his work with weeds than does A. H. Larson.

May I read this citation to you.

THE NORTH CENTRAL WEED CONTROL CONFERENCE
presents
Alvin H. Larson
with an
Honorary Membership

In recognition of his pioneer work in weed studies, his stimulatiing influence as a teacher of Agricultural Botany at the University of Minnesota, and his service as an advisor to various weed control groups in the State for over thirty years.

In witness whereof this certificate is signed by the presiding officers of the North Central Weed Control Conference, December, 1949.

R. S. Dunham, President — Glenn Viehmeyer, Vice President

E. A. Helgeson
Secretary-Treasurer

It is with great pleasure, Al, that I award you this Certificate of Honorary Membership in the N. C. W. Control Conf.

Weed Control in the Agricultural Research Program

K. S. Quisenberry

It would be the height of folly for me to attempt to discuss the technical phases of weed control before this Sixth Annual North Central Weed Control Conference. Most of you are actively engaged in such work and are well posted on the most recent developments, especially since attending the previous sessions of this conference. For this reason I should like to limit my remarks to some of the general questions that are constantly being raised in this rapidly expanding field. Possibly by presenting my views on some of these questions you well be encouraged to give more thought to the plans being developed and thus set up a still more effecient research program. Since I am not actively engaged in any specific phase of weed control research it may be possible for me to present a slightly different picture and point out how some phases of the work look to an outsider. At least this will be my aim, and I hope that my remarks will be received in the constructive way they will be given.

Chemicals Not the Only Way to Kill Weeds

You have just heard a complete and well-presented discussion of the control of weeds by cultural practices. Such a discussion is especially fitting at this time since so much of the weed control research work is now centered around the use of chemicals. One almost might conclude that cultural practices have failed completely, yet we know this is not so. Results with herbicides have been little short of phenomenal, but we must not forget that proper cultural practices, crop rotations, soils, and range management, are basic requirements in most effective weed control proprams. There is nothing new about this viewpoint of course, but to me it seems important yet easily forgotten. In a well-balanced program all possible methods of control must be and are being considered.

It is probably true that proper cultural methods are still the most economical to use. When we gain more knowledge regarding the details of plant growth such as life history, seeding habits, germination of seed, and response to variations in environment, it should be possible to take advantage of the weak points in the life cycle, and by proper adjustment of planting dates, methods of planting, and type of rotations to establish conditions less favorable for the weeds.

In spite of the outstanding success with chemicals, some workers still consider them as only an ace in the hole, to be used when all other methods fail or are impractical.

Precautions Should be Emphasized

Workers in this area are, in my opinion, to be highly commended for the care they have exercised in making recommendations and in cautioning prospective users concerning the dangers in the use of certain chemicals. Each of you is well aware of the disastrous results which may follow if some of the more potent chemicals reach susceptible crops. Damage has ranged from a few flowers or vegetables in a back yard to serious damage to crops over a wide area. Had it not been for this care drastic legislation and regulations would undoubtedly have been enacted. All of us, I am sure, are in favor of such laws as are necessary but I am equally certain you will agree that as far as possible it is better to take care of these matters voluntarily. In traveling over the country I have heard of instances where herbicides were still being recommended and sold by individuals who knew little or nothing about the effects of the chemicals, or proper ways to use them, and less about the weeds and crops involved. I am sure that our better informed commercial associates are well aware of these facts and realize the need of caution in promoting sales campaigns until such time as sufficient data are available to provide safe recommendations. It may not be possible to sell as much material this year, but a lot more will be sold in the years to come if overselling is avoided. There is a continuing need of full consideration to more careful wording of advertising copy, and of the directions accompanying the herbicides. In some cases precautions are not being given sufficient emphasis.

We cannot foresee all of the possible consequences or side-effects of the use of new herbicides, but we can at least profit by the past, and at times bitter, experience with 2,4-D. Early in the developmental stage —concurrent with testing of herbicidal efficacy—sufficient chemical, physical, and toxicological data should be obtained in order to know the limitations and precautions which eventually must be observed in applying these weed-killers in the field. If we do not profit by past experience to the degree that we are able to anticipate future developments, then individually and collectively we lack the circumspection that is the mark of true research scientists. Of course, all of you know this much better than I do.

Effect of Chemicals on Crops

While most of the attention is devoted to the question of controlling or eradicating the weeds, it is pleasing to note that considerable thought is being given to the effect of the treatment on the crop. To be successful the weed treatment must not impair the quality of the crop, and it is best if there is no damage to the crop plants. So far as cultural practices are concerned there is probably no effect on quality or yield other than to improve both, provided good practices are followed. This is not so true with the use of herbicides.

Where the crop is to be used for human consumption neither the taste nor the storage characteristics dare to be changed. In some cases there have been reports of injury not only to the current crop, but also to germination of the seed from that crop. In the case of wheat, in the absence of weeds, it has been shown that 2,4-D will cause an increase in protein content, but usually there is a proportionate decrease in yield. Also, it has been shown that small grains harvested from plants injured by 2,4-D will show a reduction in vigor but not in percent of germination.

In the case of cotton, grassy weeds are presenting a serious obstacle to mechanical picking of the crop. There, weeds come into the fields after the crop is "laid by" and when the picker comes along, especially

the spindle type the trash and fiber from the grass becomes mixed with the cotton. At present there is no mechanical equipment available to separate the cotton fiber from this trash, therefore it is a most serious problem. Elimination of these weeds will be a real help to the cotton mechanization program.

In several crops it has been shown that varieties differ in susceptibility to injury by certain chemicals such as 2,4-D. This is true in the case of flax, wheat, oats, and possibly other crops. In the case of corn it has been found that inbreds differ in reaction to the chemical and that these differences are carried over into single and double crosses. Not long ago a prominent plant breeder said "No doubt we should start to breed wheat for resistance to 2,4-D". If we are ready to admit that chemical weed killers are here to stay, and I believe they are, then our plant breeders should include chemical tolerance in their parental material. Plant breeders may reply that by the time the new variety is ready for general distribution the weed-killer or the formulation will be drastically changed. Undoubtedly the details of the use of 2,4-D and other herbicides probably will be greatly improved over present practices, but, I believe, the chemical is firmly intrenched as an agricultural practice. While it is dangerous to make predictions, it is hard to believe that within the next generation a new compound will be found that is equally versatile and will completely supplant 2,4-D so far as crop weeding is concerned. It would seem therefore, that some work must be directed in this field.

Cooperation

When work on weed control research was started in earnest some 12 or 15 years ago, the research staffs were extremely limited and funds were pitifully meager. This often made it necessary for one man to do all the work at a given location. He had to be a specialist in physiology, chemistry, ecology, botany, machinery, agronomy, plot techniques, and extension. It is surprising how much progress was made and how many of the more pressing problems were solved under these conditions. Funds for weed control research have increased in recent years, many more workers are on the job, more precise methods are being demanded and more careful work is needed. Scientists with diverse training are now being employed. While this is a most desirable change, and a goal toward which all have been striving it does give cause for careful planning or the talents of some members of theteam will be wasted.

Let me be more specific. At a recent meeting of plant scientists, I heard three plant men each spend considerable time explaining the fine points of spray machines to be used for small plot work. Unquestionably these machines were well designed and were efficient in operation. How much time these men spent in the actual design and construction of these machines was not explained, but my guess is that it was considerable. Would it not have been more efficient for agricultural engineers or commercial machinery companies to build these machines based on specifications drawn up by or in cooperation with the plant men. The man knowing plants and chemicals would then have more time to devote to the things for which he is trained and does well. This same argument could be applied to other related fields in which there are well-trained scientists at almost every experiment station in the country.

On the other side of the picture, I know of recommendations made by agricultural engineers that were at variance with those being made by agronomists in the same area. You will all agree, I believe, that such a condition is not desirable because in the eyes of the farmer no distinction are likely to be made between engineers and agronomists.

Research workers often are criticized for becoming too specialized. I am arguing for specialization of effort, but not specialization of knowledge. In other words we need to get all phases of specialization into the over-all program. Each man should know his field thoroughly, but he should be informed on the entire story. Then when recommendations go out they should be uniform regardless of who makes them always being careful to give credit where credit is due. Marked differences of opinion mean that the problem is not solved and that recommendations are premature or at least should be provisional. If workers at a station or in an area are familiar with the entire program and are working together there will be fewer difficulties of this sort.

Some of you are saying "Practice what you preach". I will be the first to admit that in an organization as large and far-flung as the United States Department of Agriculture there is not always the degree of coordination and integration we like to see. Recognition of a defect is the first step in correcting it. In the Bureau of Plant Industry, Soils, and Agricultural Engineering a special committee has been set up to consider this matter. On this committee is a representative of each Division doing work on, or having an interest in, weed control. The purpose of the committee is to act as a clearing house on work under way, or contemplated and thus keeping all informed as to what is going on. Progress is slow but we believe we are moving in the right direction. It is known that various Agricultural Experiment Stations have similar committees.

In all sections of the United States Advisory Committees for weed control research have been organized under the Research and marketing Act of 1946. There is such a committee in this region, and it is to have a meeting in connection with this conference. The function of this committee, as I understand it, will be to examine and integrate all weed control research now under way, as well as to plan new work and make recommendations for the support and execution of the projects. Funds going to the several states, as well as the Federal agencies will support this work, and the whole program will operate as an integrated unit. If the project develops as it should, a more complete coverage will be possible and as a result information can be obtained more efficiently. To date the Research and Marketing Administration has done a great service in bringing workers together for planning conferences which are bound to bring about a more integrated plan of attack.

With the discovery of the herbicidal value of certain chemical compounds many commercial companies organized research programs. Most of this work has liberal support, is well-planned, and conducted by

competent scientists. These programs have and are continuing to contribute much useful information. Wherever financial interests are involved, there is, unfortunately perhaps, a tendancy to suspect bias. But bias is not limited to commercial companies. For these and other reasons constant checking and rechecking of experimental results by all agencies concerned is always desirable. The underlying attitude should be to "know" rather than to prove something.

Pre-Mature Publication of Results

Because of the urgent need for information it has been necessary to publish results and make recommendations based on tests conducted at a single location for one year. In the proceedings of this and other conferences many abstracts are presented giving data from a single year's test. If properly understood and evaluted such reports are of value, but if taken as the final answer they can be most misleading. No doubt most of these findings have been or can be repeated if conducted under similar conditions of climate and growth. But how often is it possible to exactly duplicate climatic conditions in the field? All research workers feel that there should be an adequate sampling of the seasons before a final answer be given. Would it not be well, therefore, to consider rather carefully if data based on a single year's tests should be given wide publication? More and more contributions are being based on results of 2, 3, or more years, or results at several stations, and these should have more consideration.

A few years ago, in this general region one year's work indicated that pre-emergence treatments would be a practical method for controlling weeds in corn. Many people, myself included, visualized discarding cultivating machinery. The very next year, and in years since the results were far less promising because weather conditions were not favorable.

Another question that gives weed control workers considerable concern has to do with the formulations being made available. Experiments are started using a given herbicide. The next year it is impossible to obtain a supply of this material, the answer being that the formulation is no longer available but a substitute is being offered. This causes the research worker much concern, since the material is not readily available. Possibly one answer would be to confine the tests to screening experiments on very small plots or in a greenhouse until such time as enough information is at hand to indicate the value of the product and possibility of a commercial supply if it has promise. Another might be to have some central agency such as the Bureau of Plant Industry, Soils, and Agricultural Engineering make up the pure compounds of the basic active ingredients and make these available for use by all workers cooperating in the weed program. By using the pure compounds with one or two standard solvents it would be possible to make comparisons on a year to year basis and also to use these compounds as the basic standard for a comparison of commercial formulations.

For the most part, weed control work in the field must be done where the weeds are serious. This means going to the weeds, thus making necessary the transportation of men and equipment a considerable distance, and scattering the research work over a wide area. In some cases workers are now trying to establish uniform stands of certain weed species on experiment stations, and then concentrate the work on these stands. The practice of actually sowing weeds may be open to serious question, but it would seem to be one way of improving experimental techniques and reducing the time spent on the road.

Basic Research in Weed Control

Another problem that merits attention from overall administrators to the field men working on a specific problem is the place of basic or fundamental research in the weed control program. This problem has encouraged a lot of thinking—some of it rather loose—and often characterized on the one hand by emphasis on the need for basic or fundamental research, and on the other by stressing the fact that the research must be practical. Usually there is no very clear concept of what is and what is not basic research, or how one can conduct basic research if all of the funds are tied up with practical research or vice versa.

Most research of the United States Department of Agriculture and the Agricultural Experiment Stations grows out of a public demand for the solution of some practical problem—not out of a demand for research per se. Congress and the State legislatures constantly demand practical results and are impatient if a research agency seems to spend too much time or effort on pure science. The result is that scientists in these institutions cannot pick posies in every garden nor chase rabbits wherever they may be found. Farmers, for example, want to know how, when, and where not to use 2,4-D and are not at all concerned about wetting agents, whether the acid is translocated in the phloem or xylem, or whether translocation is related to carbohydrates or to something else. Yet those directly concerned with the research problem know that information on how 2,4-D and other herbicides get into the plant and how and under what conditions it is translocated to the roots or other vulnerable tissue is necessary to the most effective use of herbicides and especially necessary in extending their use to other weeds and other crops, and in areas where they have not been effective.

A part of the dilemma can be resolved I believe by a better understanding of what we mean by basic or fundamental research. To many it connotes something mysterious and difficult to understand; complicated laboratory apparatus, abstruse mathematic calculations, and difficult to understand chemical formulae. Often it does involve these things but not necessarily so. To me basic or fundamental research is nothing more nor less than an attempt to set up experiments or make observations that will provide a better understanding of the phenomena with which we are dealing. It may be no more complicated than finding that weeds are not killed by certain chemicals because they will not adhere to the leaves or that certain weeds do not thrive in some crops because of the shading effect. Another example—in a field with which I am more familiar—would be a study of the temperature and moisture conditions related to a di-

sease of cereal crops or life history studies of that disease if not already known.

I am sure most of you will agree that we need more information of this kind. We also need more of the kind that can be conducted only in the greenhouse or laboratory, but at the same time we must get the practical answers to satisfy the farmer and others. The crux of the problem, as I see it, is to maintain a proper balance between these various types of research. It is not so much a question of whether a proposed study is basic or practical as it is "will it give us the information we need most to answer the problem at hand." In other words, we should ask ourselves not whether we should conduct basic or practical research but rather will the research we are doing or contemplate doing answer the questions that need to be answered. Simple problems can often be answered by simple empirical experiments; more complex ones cannot. But we can be easily misled into thinking a problem is simple and easily solved when, as a matter of fact, it may be very complex. Science is replete with examples of man's tendancy to overestimate his own ability, and to misunderstand nature's complexity.

Much of the responsibility for proper balance rests upon the administrators in the allocation of funds. But much can also be done and is being done by the field personnel in striving to determine "Why?" as well as "How?" Field personnel can also be of much help in pointing up problems that require greenhouse or laboratory study, in determining the limits beyond which field studies can go, and in helping to decide what kind of greenhouse or laboratory studies—basic research if you prefer—are neseccary or are likely to be profitable. Because our research is financed entirely or almost entirely by public funds we must be certain as is possible that whatever studies are undertaken will yield the results we need. Such results usually are not, nor need they be, immediately practicable, but they should contribute to an understanding of a practical problem. If they do this much we can be reasonably sure that a practical use of them will eventually be found.

UNIFORM TRIALS

There is another point I would like to stress although it does no more than emphasize what is now a general practice throughout the area; viz. the value of uniform experiments over a wide region. I am sure you realize the value of these tests as well as or better than I do. It seems to me, however, that because of the rapid development of chemical control methods, and perhaps also because of insufficient opportunity for workers to get together to plan their work there has been less attention to this feature of the program than its importance merits. It may be that my impressions arise more from the fact that no adequate machinery is set up to put the results together and interpret them rather than to any lack of diligence in setting up the experiments. I noted, for example, that the Report of the North Central Weed Control Conference for last year contained something like 396 abstracts on weed control experiments of which practically all related to herbicides. This obviously represents an enormous amount of work widely scattered from East to West and North to South. Your research committee performed a stupendous task in getting this material together as well as they did. I have no reason to think that the recommendations derived from these abstracts are in any respects unsound or questionable. However, I seriously question the ability of any group—regardless of how competent it may be—to adequately summarize, digest, and critically interpret such a mass of data in the space of 1 or 2 days. No doubt you are doing the best that can be done under the circumstances, but would it not be well to consider methods whereby more time can be given to the interpretation of data and possibly the planning of the experiments from which the data are derived. From th standpoint of the research worker that is the real reason for being present at a conference such as this.

The points discussed are ones which, in my opinion, need careful consideration at this time. Many of you are giving serious attention to the organization of the weed control work as it is now being expanded. If any of my remarks sounded critical, please understand that they were not meant that way but were made with the hope that they will be taken as constructive suggestions. The workers of this conference have been and are doing a fine job, and are going to continue to do a fine job. It should be remembered that in this case we are interested in control or eradication of plants. Are we sure that the same experimental methods that have been used so successfully in learning how to grow better crops will be the best to use for the problem at hand. No doubt the answer is yes, but before we accept such an answer all should give the matter careful thought.

In conclusion, may I say that it has been a great pleasure to have this opportunity to attend this conference and appear on the program. I want to thank you for the courteous attention you have given to my remarks.

Screening of New Selective Herbicides

L. M. Stahler

In present day investigations concerned with development or use of herbicides the importance of selective herbicides cannot be underestimated. The thirteen North Central States last year treated approximately 15 million acres with 2,4-D for weed control and it is reasonably safe to say that 4/5 of this area, or twelve million acres, was in growing crop at the time of application. The fact is very evident that the elimination of annual weeds in growing crops or the control of perennial weeds in growing crops is a much more important consideration than the use of herbicides primarily for the control of perennial weeds without consideration of their herbicidal effect on crop plants.

All of us in weed control or herbicilal investigations are therefore confronted with two important problems in considering the possible use or development of any of the new herbicidal compounds. The first of these considerations are: (1) Does the material have phytotoxic qualities when applied to weeds; (2) Are

these phytotoxic properties expressed on the crop plants whose culture is hampered by specific weed species?

Naturally we have other considerations in testing, or developing uses for the new chemical compounds as herbicides—such as solubility or miscibility of the material in spray carriers; the stability or residual action of the material when applied to crop plants or the soil; the volatility and drift hazards, and the effect on warm blooded animals. All of these latter factors are of secondary consideration, however, and if we find that the chemical material possesses herbicidal qualities of real promise we can depend on the chemists and formulators to recombine or reformulate the materials so as to overcome many of these drawbacks.

The unit cost of the material in laboratory and pilot plant quantities should be of no consideration in screening test stages of development of a new herbicide. Many of you recall that 2,4-D in its original experimental form had a value of from $5.00 to $12.00 per pound of acid. Yet today with volume production and consumption the actual cost of 2,4-D to the consumer is less than the cost of applying the material.

I believe that in some cases we have actually missed the boat on some promising herbicides by allowing a consideration of economics to limit our investigations. As an example, the fact that 2-methyl-4-chloro-phenoxyacetate, was priced far above 2,4-D on a unit basis led many of us to discontinue investigations of MCP early in its development. The few investigators who have continued to work with MCP regardless of its economic position are finding that it has certain unique qualities as a selective herbicide that may favor its wide use—this in turn will bring about an ultimate decrease in cost of production and consumption and place it in a much more favorable economic position with 2,4-D.

With the older type of herbicides preceding 2,4-D, and the dinitro compounds, our problems were relatively simple. We assumed that the cost of eradication of weeds with chemical herbicides would be high; we took for granted that residual soil sterility would be a problem and devoted our time and energies to studies of dates and rates of application, soil types and predictable seasonal weather phenomena that would improve or increase the herbicidal properties of these materials. We were working with materials such as sodium chlorate, sodium arsenite, sodium tetraborate and carbon bisulfide. The herbicidal properties of these materials were well established and we took for granted that their cost in use would often be equal to the value of the land on which they were applied.

With the release of 2,4-D a concerted and extensive trial and error testing program developed. Certainly no other single agricultural development has so rapidly and so extensively been accepted by the farmers in this area. Yet we as a research group have contributed little to improve or change the original formulations of 2,4-D materials available. Actually the ease of formulation of the several types of 2,4-D and the efficiency or use in application of these formulations were the prime factors that determined the relative position of the several formulations now in greatest use. The concerted action of groups such as our NCWCC is largely responsible for the uniformity and specificity in recommendations for use of 2,4-D and certainly the acceptance of these uses in so short a time and on such an extensive basis is a development that we can all be justifiably proud of having a part. On the other hand, our limited knowledge of the basic physiological and chemical factors concerned with the action of 2,4-D as a selective herbicide reflects a lack of interest, understanding or perspective that neither does us credit nor offers us any entirely dependable basis for critical consideration of either 2,4-D or the newer herbicides that are appearing in ever increasing numbers.

Commercial research teams deserve credit for most improvements that have been made in new formulations of 2,4-D developed in the past year or so. I am thinking in particular of the new low volatility esters and the new amides. These formulations while yet in the experimental stage, promise to open a whole new field of development in formulations of 2,4-D and 2,4,5-T. Further, there are indications that these newer formulations will be more selective in their action and more specific in ultimate use than those presently available and widely used. These developments will complicate our problems and necessitate a more refined system of screening tests than we have hitherto employed. I have been unable to find data concerned with 2,4-D—either basic or empirical that would permit a logical estimation or forecast of the efficiency or selectivity of any of the newer types of 2,4-D that have, or will be, released for testing purposes.

Actually we are in the position that plant breeders would be if they knew nothing of the pedigree or parentage of new varieties with which they are concerned, and would thus of a necessity start each season with a new list of varieties and be forced by simple empirical field plot tests to determine the relative merit of each. To further complicate the problems of these plant breeders, let us suppose for the moment that they receive new varieties of crops without any information as to the milling and baking qualities, disease resistance, or whether they are spring or fall varieties. Let us say that these samples of new varieties are sent indiscriminately to all experiment stations from California to Maine and from Florida to Saskatchewan. Let us further complicate this picture by having each of the crop investigators receive several samples of the same variety each under a different designation. Under these hypothetical conditions, the plant breeder who developed an excellent variety of hard spring wheat is assured of having adverse reports of its performance from many of the stations to which he submitted it. He can be assured that it will take years to arrive at a valid estimation of the future worth of his new variety. The individual at the experiment stations starting off with a hodge-podge of adapted and unadapted varieties with no knowledge of the past performance of any of them will find his program so extensive and complicated that he will be unable to derive data that will permit a logical evaluation of even his best and adapted varieties. Certainly this hypothetical set-up would be

a most illogical and impractical method of meeting the demand for development and recommendations of new varieties of cereals. It is just as illogical when we consider that in the screening tests and development of new herbicides we have been following precisely the same haphazard system of procedure.

This past season and previously I have seen unopened experimental samples of herbicides on the laboratory shelves all over the North Central area. The total volume of these wasted and often expensive materials would run into hundreds of gallons. In other cases, investigators attempt to make token applications of every possible type of herbicide sent them by commercial formulators. Often these efforts represent a single application made without regard to consideration of rate, date or growing conditions. In many of these cases the experimental materials should have been left on the laboratory shelf. Data from these token applications—regardless of their validity are bound to influence all of us in drawing up policy reports regarding future use or recommendations for development of these new materials. In the cases mentioned above, I believe that the manufacturers and distributors of the new formulations of herbicides have been largely at fault. Where do the commercial people get the lists of investigators to whom they send samples of their new materials, mixtures or formulations? Why do they not send more of the background and basic laboratory and greenhouse data to the investigators along with the samples of their new formulations? When I receive a sample of a supposedly new herbicide without the laboratory or field data to indicate its possible use and herbicidal value, or without any indications of its basic formula or ingredients, I take for granted that the formulator has more hope than data to justify the formulation and I disregard it. Unless commercial formulators have enough confidence in the institutional research men to furnish these data, I do not feel that they are entitled to the benefits which they hope to derive from our field tests. If they do not have these data, they have not carried their formulations or materials far enough to justify our attention. Having these background data and records of performance the individual investigator should logically decide whether his interests and available facilities justify his testing of the herbicide. In past years with the relatively few really new herbicides and new formulations of old herbicides, the average investigator has solved those problems rather simply. In the coming year and each successive year, these problems will become more confounding and complicated.

This past year a number of commercial formulators have made up experimental quantities of the maleic acid hydrazides, thalmic acid derivatives, xanthogen compounds and trichloroacetic acid derivatives. I know of at least twenty new materials of possible herbicidal nature representing these groups alone that were not available a year ago. Within these groups there are possibilities for the formulation of hundreds of analogues,mixtures and special formulations. We have indications that some of the already available new materials have reasonable herbicidal qualities, are highly specific, and more highly selective than any thing we have hitherto investigated. In my news letters this past season I have several times touched on some of these new materials which we at the Brookings, South Dakota Station, and others, have had under preliminary screening tests. A consideration of these factors prompts us to realize that in order to keep abreast of these new developments we must in some way reorganize and coordinate our initial and prliminary screening test programs concerned with herbicides.

In undertaking screening tests of newly formulated herbicides or in conducting our field tests for the development of uses and recommendations for the older herbicides, we have a double responsibility that I have been surprised to find is not recognized by some investigators. In the first place, we have a real responsibility to the commercial group that developed and manufactured the new product. We must fully appreciate the time, effort, and capital that has been involved in the initial stages of compounding, formulation, and testing of this new material before it is released for field testing. We must fully realize that the commercial organization presenting a new formulation or chemical for test is fully convinced that this material has a possible specific and economic use in our field. The day is past when commercial manufacturers bottle or barrel a bi-product of some commercial chemical process and hopefully attempt to sell it as an herbicide. The reputable commercial organizations with which we deal today maintain a staff of agronomists, physiologists and chemists that starts the formulation of a new herbicidal material on the basis of a survey for specific need or uses; then, through the field of special formulation of specific materials to fill this need, selective testing and elimination of these special products to determine their relative efficiency in use, and finally formulation of these specific products in the most usable and economic form. Most of the commercial manufacturers will furnish the field investigator the background data accumulated through these processes of development with the original sample of the material to be tested in field plots.

I need not emphasize the responsibility we have to the consumer of the materials that we test and finally recommend for field use. Again referring to the fact that approximately 15 million acres in the North Central States were treated with 2,4-D this past year—largely on the basis of your recommendations this parallel responsibility is sufficiently emphasized. Our conservatism in recommendations for the use of 2,4-D in the past years, has I believe, been well justified and rewarded by the relatively few instances of damage and dissatisfaction resulting from the use of this material. I am further reminded with a sense of real satisfaction your cooperative and timely response to the question of the use and recommendations of 2,4-D as a pre-emergence application for the control of weeds in corn and other crops. Data since derived have well established the fact that your approval of this practice would have been tragic.

How can we best handle the problem of new herbicides in future years? While I am confident that we will develop an efficient workable system, I have only suggestions derived from talking with many of you this past year to offer at the present time.

Many of you have suggested, and I agree, that we need a more efficient equitable system of distribution of new herbicides and herbicide formulations that will eliminate waste of materials for the producer and assure the logical investigator of obtaining adequate test samples early in the developmental period. As I indicated before, it is illogical and wasteful to send test samples of a new herbicide designed for the control of woody plants to investigators whose primary interest is control of grasses in cotton or annual weeds in spring wheat. It is just as illogical and wasteful to send materials which have shown unique selective properties for the control of annual weeds in garden beans to those primarily interested in the control of woody plants. Not alone is it illogical and wasteful, but it is unfair to the herbicidal material itself as the complications and specifications of the new herbicidal materials require a real knowledge of specific crop culture and practices in order to logically evaluate their possible utility. Several of you have suggested that we could some way establish a central clearing house for new herbicides with one or more investigators designated to suggest to the commercial manufacturers the investigators who should logically receive new materials and on the basis of their earlier developmental data and possible application. Establishment of this type of distribution center, or expediting group or individual, cannot be simply accomplished insofar as it would require the cooperation of the commercial formulators as well as the institutional research personnel. Needless to say, it would require considerable time on the part of the one or more individuals who accepted this responsibility and require a broad and current knowledge of chemical herbicide developments as well as an extensive and current knowledge of the problems, interests and facilities of all investigators in the area concerned.

In order to efficiently expedite the development and field use of the new herbicides, it is essential that we develop and, if possible, standardize preliminary screening tests in order to classify the new materials on a functional standardized basis. In this consideration, a wide basic knowledge of the physiology of action of these herbicides would be a real aid in establishing a simple mathematical measure of their efficiency. Insofar as we do not as yet have a satisfactory basis for evaluating 2,4-D formulations on this basis, we cannot hope to be provided with these technicological guide posts or rulers in our current consideration of the new materials now appearing. Therefore, we are forced to consider morphological responses to these materials based on our knowledge of the culture or normal developments of the crops and weeds under consideration in establishing minimum requirements of performance on which to base field newer herbicidal materials now available is the untests beyond the screening test stage.

A problem that we will all encounter in testing the certainty of measuring their efficiency on the basis of the reactions that they induce in weed or crop plants. It is not now a question of determining whether a plant is dead or alive, we must determine the degree of vitality exhibited by a plant after treatment with one of the new growth regulating materials and further estimate its potential for recovery and development. This is particularly true in the consideration of annual weeds. A plant of green foxtail treated with one of the new maleic acid derivatives that does not develop beyond the four leaf stage in a normal growing season, but is yet alive at the time of killing frost, represents a unique degree of control attained through chemical herbicides that we have not experienced before and a degree of control that requires new terminology and techniques in recording data. Only with a thorough knowledge of the normal growth and development of the crop plants and weed plants under consideration can the investigator working with some of the new growth regulating herbicides hope to make a fair estimation of their activity and efficiency.

The real purpose of this paper is to present for your consideration, criticism and suggestions, a screening test procedure that we at the Agronomy Department of South Dakota State College devised and used this past season. At the outset I will say that these screening tests were devised purely as a preliminary elimination process. We attempted to include a representative and selected number of crops, weeds and herbicides without complicating the experiment to the point where land and labor would be limiting factors. Plot size was reduced to a functional minimum in order that crops and treatments could be included on a relatively uniform area. All crops were planted in rows permitting of tractor cultivation in order to reduce labor to a minimum and also to insure uniform depth of planting and stand of crop. Single spray strips of four foot width were used as raw plots with four replications, and plots and treatments were laid out on a systematic basis rather than being randomized in order to facilitate uniform and accurate application of the test material. Herbicides were tested as both preemergence and postemergence applications, the preemergence treatments being made approximately two days before emergence of the crops, the postemergence treatments when spring germination of grass and broadleaved weeds was considered to be accomplished. Two rates of application were used in both preemergence and postemergence treatments of all herbicides. The lower or basic rate was determined as optimum with the second rate double the basic.

Plot rows were cultivated with a tractor cultivator with the inner sweep set so as to leave a strip eight inches on each side of the row. No hand weeding or hoeing was used on any of the plot area which was weed infested with green foxtail, *S. veridas*, yellow foxtail, *S. glauca*, barnyard grass, *E. crusgali*, wild oats, *A. fatua* and pigweed, *A. retroflexus*, lambsquarters, *C. album*, and kochia, *K. scoparia*.

In determining the relative efficiency of the various herbicides used in these screening tests stand count and vigor of surviving plants was considered and expressed as a percentage of the stand and vigor respectively of the untreated check plots. In establishing a comparable tolerance rating of crops to the various herbicides tested a tolerance rating was derived by multiplying stand times vigor and dividing by ten. In determining the efficiency of the various herbicides in control of the weed population, broadleaved weeds, and annual grass weeds were considered independent-

ly. A herbicidal rating was established by multiplying the stand times vigor factors and subtracting this sum from a basic one thousand in order to indicate the positive value of the herbicide. The factors of crop or weed stand and vigor were determined separately on each of the four replicated treatments and averaged to secure the data shown in later tables.

The only unique factor in this preliminary screening process is the fact that we considered vigor of plants as well as survival as a measure of crop tolerance or herbicidal value of the chemicals tested. Actually our vigor rating amounts to "weighting" data of survival on a realistic basis. To adequately estimate vigor of crop plants and weeds under consideration, their morphology, growth, and rate of development must be fully familiar to the investigator. A careful examination of the entire plant must be made to determine possible injury to roots and growing point. This is particularly true with the newer herbicides that have a stunting or deterring action on plant growth and development.

Among the herbicides included in our screening tests that will be discussed here were three 2,4-D formulations; LFN-472, a micronized acid suspension of 2,4-D with which many of you are familiar, LFN-646, a micronized acid emulsion of 2,4-D and LFN-648, an amide formulation of 2,4-D. These materials were all furnished through the courtesy of the American Chemical Paint Company. As representatives of the newer growth regulating herbicides we had E.H. 1, the sodium 2,4-dichlorophenyl "cellosolve" sulfate, and E.H. 2, dichloral urea furnished by Carbide and Carbon Chemicals Corporation. Sharples Chemical Company formulated and supplied E.C. 3321, an anhydride of maleic anhydride which is essentially 3, 6-endoxo-tetra-hydrophthalic anhydride; E.C. 3441 which is a hydrogenation derivative of the above, (3,6-endoxohydrophthalic acid) and E.C. 3440 which is a disodium salt of E.C. 3441. XP40A—a formulation of 5 pounds xanthogen disulfide per gallon was furnished by Sherwin Williams Paint Company. For purposes of comparison we included some of the older and more standard types of herbicides such as IPC, Borax and cyannate.

Further, I want to emphasize that these are screening test data, and that the investigation was planned and undertaken to derive some indication of the necessity or advisability of continuing further investigations of these selected materials. Further, investigations of most promising materials included in these tests are being undertaken at the present time in the greenhouse at Brookings and also at the State College at Fargo, North Dakota. I am confident that in 1950 many of you will include them in your field tests and that they or their derivatives or analogues will eventually become important new tools in our weed control programs.

The data that we are presenting here refer only to preemergence applications. In Table 1, are the summarized *tolerance rating* of commercial sunflowers and the *herbicidal rating* of annual grass and broadleaved weeds for nine selected herbicides. This table, and that following, are presented to show the relationship between the estimated *stand* and *vigor* determinations in establishing the *tolerance rating* on crops, and the *herbicidal rating* on annual weeds in these screening test data. We feel that the data of Tables 1 and 2 represent the minimum necessary for a fair preliminary evaluation of a selective herbicide.

On the basis of the data of our preliminary tests we feel that a tolerance rating of 800 or better justifies further testing of an herbicide that under identical conditions shows a herbicidal rating of 700 or better on either grass or broadleaved weeds. Adjustments in rates, dates, or methods of application—problems of later investigations, may reasonably fit such herbicides to specific and acceptable uses. Herbicides falling below these minimums in specific crop tolerance rating or herbicidal rating respectively, will hardly justify further investigation effort.

On this basis of screening only E.H. 2, E.C. 3440, E.C. 3441, LFN-646 and LFN-648 are suggested for further testing by the data of Table 1.

Data in Table 2 suggest that in investigations concerned with control of annual weeds in flax, in addition to the materials indicated above, LFN-472, and E.C. 3441, should be further screened. Data in Table 2 concerned with tolerance of barley indicate only E.H. 2 and LFN-472 as meeting the arbitrary minimum standards of performance which we feel make them worthy of further investigation. Note that LFN-646 and LFN-648 were not included in data of Table 2.

Data in Table 3 are presented to indicate the marked selectivity of specificity of herbicidal action of the selected chemical formulations tested. Note particularly that E.H. 1 at rates tested, while having a low, but definite, herbicidal effect on either flax or soybeans indicating that further testing at higher rates of application is desirable. A further study of the data concerned with E.H. 1 in Table 3 would indicate that it demonstrated a greater degree of species selectivity in herbicidal action than any other material included.

E.C. 3440—the disodium salt of 3,6-endoxohydrophthalic acid is indicated by data of Table 3 to possess a most remarkable degree of selectivity in herbicidal action between monocots and dicots.

How will cotton, alfalfa, clovers, peas, tomatoes and other important vegetable crops react to the herbicides just discussed? Do the new herbicides now available have specific or selective qualities more desirable or more well defined than those just discussed? In answering these questions our field of investigation will certainly become more diversified, more complex and above all, more intrigueing in perspective as well as accomplishment.

Table 1. — Screening test rating of herbicides when applied as pre-emergence treatments on commercial sunflowers, annual grasses and broadleaved weeds. Brookings, South Dakota, 1949.

Herbicide used	Rate in lbs. per acre	Tolerance rating: Sunflowers Stand	Vigor	T. R. 1/	Herbicidal rating: Grass weeds Stand	Vigor	H. R. 2/	Broadleaved weeds Stand	Vigor	H. R.
E. H. 1	2	22	40	88	86	80	300	100	80	200
E. H. 1	4	34	30	102	58	80	540	80	90	280
Check	—	100	100	1000	1000	100	100	0	100	100	0
E. H. 2	2	100	80	800	30	80	760	100	90	100
E. H. 2	4	100	40	400	30	30	910	100	65	350
E. C. 3440	2	100	100	1000	12	10	988	100	100	0
E. C. 3440	4	100	100	1000	0	0	1000	100	100	0
Check	.....	100	100	1000	100	100	0	100	100	0
E. C. 3441	2	100	100	1000	80	40	680	100	100	0
E. C. 3441	4	100	100	1000	40	60	760	100	100	0
E. C. 3321	2	100	90	900	65	85	480	85	100	150
E. C. 3321	4	100	90	900	70	80	440	100	80	200
XP-40A	5	100	100	1000	92	100	80	68	100	320
XP-40A	10	100	100	1000	86	100	140	35	100	650
Check	—	100	100	1000	100	100	0	100	100	0
LFN-472	1	74	50	370	32	15	968	65	100	350
LFN-472	2	34	40	136	50	10	950	32	50	840
LFN-646	1	100	80	800	24	20	952	35	30	895
LFN-646	2	100	70	700	18	10	982	30	40	880
LFN-648	1	100	90	900	41	20	918	16	20	968
LFN-648	2	68	85	550	18	10	992	8	10	992
IPC	5	100	100	1000	62	80	504	95	100	50
IPC	10	100	100	1000	54	60	675	100	100	0
Check	—	100	100	1000	100	100	0	100	100	0

1 Tolerance rating factors.

2 Herbicidal rating factors.

Table 2. — Screening test rating of selected herbicides as pre-emergence treatments on flax, barley, annual grasses and broadleaved weeds. Brookings, South Dakota, 1949.

Herbicide used	Rate in lbs. per acre	Tolerance rating: Flax Stand	Vigor	T. R.	Barley Stand	Vigor	T. R.	Herbicidal rating: Grass weeds Stand	Vigor	H. R.	Broadleaved weeds Stand	Vigor	H. R.
E. H. 1	2	100	100	1000	72	90	648	75	100	250	80	100	200
E. H. 1	4	100	100	1000	80	80	640	80	60	520	80	80	360
Check	.....	100	100	.....	100	100	.....	100	100	0	100	100	0
E. H. 2	2	100	100	1000	100	80	800	30	40	880	100	80	200
E. H. 2	4	100	100	1000	100	50	500	10	40	960	60	40	760
LFN-472	1	100	100	1000	100	100	1000	40	100	600	60	80	520
LFN-472	2	100	100	1000	90	100	900	10	80	920	45	20	910
E. C. 3440	2	102	100	1000	86	60	516	75	10	925	100	100	0
E. C. 3440	4	100	100	1000	20	30	60	40	10	960	100	100	0
Check	.....	100	100	.....	100	100	.....	100	100	0	100	100	0
E. C. 3441	2	100	80	800	100	100	1000	50	100	500	85	80	320
E. C. 3441	4	100	70	700	95	70	665	35	80	720	95	80	240
E. C. 3321	2	100	100	1000	100	100	1000	70	90	370	100	100	0
E. C. 3321	4	100	100	1000	100	70	700	60	70	580	100	100	0
XP-40A	5	100	100	1000	100	100	1000	100	100	0	100	100	0
XP-40A	10	100	100	1000	100	100	1000	100	90	100	100	90	100
Check	.....	100	100	.....	100	100	.....	100	100	0	100	100	0
Polybor	320	100	50	500	100	40	400	100	60	400	100	80	200
Polybor	640	100	10	100	100	10	100	100	20	800	100	10	900
IPC	5	100	100	1000	100	100	1000	100	100	0	100	100	0
IPC	10	100	80	800	100	40	400	100	90	100	100	100	0
Check	.....	100	100	.....	100	100	.....	100	100	0	100	100	0
Cyannate	100	100	90	900	100	100	1000	100	100	0	100	100	0
Cyannate	200	100	70	700	100	60	600	100	100	0	100	100	0

Table 3. — Screening test rating of selected herbicides applied as a pre-emergence treatment on crops and annual weeds. Brookings, South Dakota, 1949.

Herbicide used	Rate in	Tolerance rating on crops:						Herbicidal rating on annual weeds:	
	lbs. per acre	Sugar beets	Soybeans	Sunflowers	Flax	Corn	Barley	Grass	Broadleaf
E. H. 1	2	450	1000	88	1000	480	648	386	194
E. H. 1	4	448	1000	102	1000	540	640	525	375
E. H. 2	2	882	552	800	1000	400	800	718	136
E. H. 2	4	900	490	400	1000	80	500	910	332
E. C. 3440	2	980	1000	1000	1000	320	516	891	0
E. C. 3440	4	920	1000	1000	1000	240	40	983	0
E. C. 3441	2	820	700	1000	800	720	1000	434	0
E. C. 3441	4	624	450	1000	700	240	665	692	106
E. C. 3321	2	1000	1000	900	1000	800	1000	329	66
E. C. 3321	4	880	1000	900	1000	490	700	538	76
XP-40A	5	1000	1000	1000	1000	800	1000	40	178
XP-40A	10	592	566	1000	1000	900	1000	268	290
LFN-472	1	260	720	370	1000	600	1000	714	664
LFN-472	2	260	480	136	1000	400	900	812	916
LFN-646	1	.....	600	800	.....	700	.....	760	725
LFN-646	2	.....	600	700	.....	560	.....	930	915
LFN-648	1	.....	800	900	.....	1000	.....	800	925
LFN-648	2	.....	700	550	.....	1000	.....	940	975
IPC	5	950	1000	1000	1000	800	1000	408	45
IPC	10	900	400	1000	500	320	400	680	110
Polybor	320	602	.....	.....	.....	.....	400	580	500
Polybor	640	352	.....	.....	.....	.....	100	860	900
Cyannate	100	630	.....	.....	900	.....	1000	0	190
Cyannate	200	216	.....	.....	700	.....	600	0	180

Basic Research in Weed Control

W. E. Loomis

Weed control with herbicidal sprays can be divided into four processes: *coverage, penetration, translocation,* and *toxicity*. Research on any of these phases is basic if it attempts to discover and to clarify the physical, chemical or physiological reactions responsible for the effects observed. Basic research, because it tells why as well as what to do, is recognized as the desirable goal of all weed control work. In our hurry to solve the myriad problems of what is essentially a new science, all of us have given too little attention to an explanation of our results. We may have felt that the methods of basic research were too involved, the interpretations too difficult, and the results too impractical. None of these are true. A careful study of 2,4-D plots sprayed at varying times before an unexpected rain can give as much information on penetration as though the rain was a planned part of the treatments, and such a spoiled experiment can yield both basic and practical information of the greatest value.

Coverage

Research on coverage is closely related to penetration, translocation and toxicity. Such research would include studies of volume and dosage, of pressures and nozzle types, of surface tension and of evaporation rates. There is increasing evidence that coarse sprays of rather high surface tension are superior for many herbicidal spray jobs. In other words that "poor" coverage may be better than "good". The explanation probably lies in the translocation processes. For quick kill, on the other hand, fine sprays with low surface tension are more effective. At least a portion of the advantage of ester mixtures is their low surface tension, caused by the carrier oil, the emulsifying agents, and in part by the ester itself. If a wetting agent, such as a commercial soapless washing powder, is added to a solution of the sodium salt the surface tension of the solution is reduced and the rate of penetration of the salt increased until the mixture resembles an ester in its action.

Penetration

The more rapid action of low-surface-tension sprays can be shown to be due to more rapid penetration. The protoplasm of leaves is covered by three layers: a waxy cuticle, a cellulose wall and a living cytoplasmic membrane. In young or rapidly growing plants and cuticle and cellulose layers are thin and permeable and the membrane is relatively unstable. Such leaves are rather easily penetrated, even by the Na-salt in water. Older plants, particularly in dry weather or on poor soil, accumulate sugars and other carbohydrates which they are unable to use in growth. Higher sugars stimulate differentiation or hardening, in which the cuticle is thickened and may form a continuous layer; the cellulose wall is thickened and perhaps partly impregnated with wax; and the entire cytoplasm as well as the membrane is toughened so that it resists both the penetration and toxic action of 2,4-D. Penetration and subsequent kill or injury are therefore reduced. In our crop species and more susceptible weeds, how-

ever, the cuticle layer is rarely continuous. When an ester spray or a salt spray with a wetting agent is used the spray penetrates into the cracks and bypasses the cuticle. Low-tension salt sprays penetrate essentially as rapidly and act as quickly as esters.

When the sodium salt of 2,4-D was applied to corn or flax at ½ pound per acre in 10 gallons of water, the addition of 1/2 per cent of a commercial soapless washing powder increased the injury as much as 10 times. Ear shoot development could be prevented by spraying just before tasseling, or cobs developed bare of grain over much of the basal end by spraying just before silking. The yield of flax was reduced from 16 bu. to 15 by 1/2 pound of amine, but to 5 bu. by the amine plus a wetting agent. These results have been shown to be due mainly to a greater and many times more rapid penetration of the 2,4-D. Kill of corn, flax or weeds is not increased, only the speed and severity of bending or other types of injury. The wetting agents alone have been nontoxic at the concentrations used, except that they increase natural smut infection in corn.

Preliminary results with soybeans washed at intervals after spraying have indicated that penetration increases logarithmically with temperature. The effects of temperature on surface tension, volatility and diffusion are considered inadequate to explain the results, which suggest some chemical reaction in the walls or at the cell membranes. If further work shows that the penetration of 2,4-D into leaves has the temperature coefficient of a chemically controlled, physiological reaction, we can visualize many applications of such basic information. An observation by Fisher and Young at Spur, Texas that adding corn sirup to amine spray increased translocation in plants in the field may possibly have been due to penetration effects and to belong in the same picture.

Translocation

Dr. Crafts has given an excellent discussion of translocation. We wish only to re-emphasize certain major points. Translocation may be due to capillary movement, as when oils are used, to backflow in the xylem or wood of the plants, or to physiologically active movement in the phloem elements of the inner bark. We suspect that much of the translocation of 2,4-D observed in past experiments has been due to movement of the first two types, with resulting poor and erratic kill of underground organs.

We know a few, but by no means all, of the answers to phloem translocation. The tissue should be actively transporting, or at least be well supplied with, food materials. Possibly moderately high temperatures are beneficial. But, most important, the phloem itself, should not be seriously injured before translocation has been accomplished. I very much doubt if a quick, and at the same time, a complete kill of resistant perennials is possible. Certainly our past failures with heavy rates of esters add up to this conclusion.

We suggest that a new attack on the control of deep-rooted perennials should attempt to obtain maximum phloem translocation by:

(1) The use of smaller doses of the more slowly toxic compounds; possibly 1/3 to 2/3 pound of 2,4,5-T, or of the sodium salt rather than the esters of 2,4-D; (2) The use of very coarse sprays so that the herbicide is concentrated in a very few drops on each leaf. Fisher and Young report that the average coverage in their most successful treatments of mesquite was three drops per leaf. Under these conditions much of the leaf will continue to function while the toxic material is fed slowly into the translocation system. Treatments which kill the leaves in less than several days to a week or more may not allow sufficient penetration of the herbicide, or may have overloaded and injured the phloem before maximum translocation was completed. (3) The spray should adhere to the leaves in a slowly available form, possibly in an emulsion of heavy, non-toxic oil, for several days. (4) Sprays should be applied in warm weather. Fisher found a correlation between translocation in mesquite and hours of temperature above 80 degrees F. It is not clear whether the effect is on penetration or translocation, although we suspect that both are concerned.

Neither rapid penetration nor rapid action is desirable. Our hope is to transport a lethal load of 2,4-D or 2,4,5-T across the phloem bridge before the bridge and its approaches, the leaves, are destroyed by the chemical. These recommendations obviously do not apply to the usual spraying of annual weeds where 2,4-D is used essentially as a differential contact spray, little translocation is required, and quick effect may be important.

Toxicity

A better understanding of the penetration and translocation of 2,4-D would lead to immediately improved control practices. A better understanding of the toxic action of our present herbicides would lead to immediate improvement of herbicidal chemicals. We have chosen yeast as the principal plant for toxicity studies which Mr. C. R. Swanson is making at Ames. It is pleasant to be able to plan an experiment in the morning, prepare the test tube plots with many replications and have the data recorded in time for afternoon coffee. Yeast of the commercial strains that Swanson has used is rather resistant to 2,4-D, surviving 6000 ppm. for 24 hours, but dying within 24 hours with 10,000 ppm. Growth is normal in the presence of 200 ppm. of the sodium salt and drops with the log of the 2,4-D concentration to zero at 5-6000 ppm. Growth is thus considerably more susceptible to 2,4-D than the viability of the cells. Respiration in a sugar solution gives an intermediate curve, turning down precipitously as lethal concentrations are reached. Very interestingly, respiration without added sugar is nearly doubled at the 6000 ppm. concentration at which death begins. This rise we interpret as protoplasmic toxicity. The variant behavior in the presence or absence of sugars may indicate a significant reaction in the toxicity of the chemical.

Staniforth's work with corn showed noteworthy toxic responses with heavier treatments or with the addition of a wetting agent. For a very short period,

possibly not more than one day, at about the 5-leaf stage, tassel development could be prevented. For another day or two branching of the tassel was reduced. For a short time just before tasseling the development of the ear shoot could be completely arrested. Later the ear shoot developed, but a nearly bare cob was produced on sprayed plants. All of these stages were so brief that it was never possible to obtain maximum effects on all of the plants of a plot. All of them appeared to represent the initiation of some new phase of meristematic development. Tassel parts, pistillate flower primordia and possibly gametophyte stages were seriously injured just at the point of change over to a new development phase.

Derscheid has obtained similar results with barley grown in South Dakota. At the first spraying in the spring of 1949 (3-5 leaves) the early Plains variety showed flower primordia and little injury. The later Wisconsin variety was apparently in the first stages of primordia development and yields were reduced 15 bu. per acre. Wisconsin was severely injured again when sprayed two weeks later and both varieties showed significant yield reductions when sprayed in early boot. Shaw and Willard of Ohio found winter wheat seriously injured by 2,4-D at the 5-leaf stage in the fall and before heading in the spring. Olson has shown the same two periods of maximum injury on spring wheat and barley in Canada and Crafts has indications that rice will show the same responses. In the small grains with their several tillers of somewhat variable stage of development the results are even more irregular than in corn, but the same pattern of susceptible stages of brief duration seems to hold.

SUMMARY

The penetration of 2,4-D into the leaves of plants may involve physiological as well as physico-chemical reactions. The processes merit careful study. Penetration is speeded on many leaves by wetting agents. The effect may be more specific than simple lowering of the surface tension.

Deep killing of the roots of woody and herbaceous perennials almost certainly depends upon downward translocation of 2,4-D in the phloem. Available data indicate that treatment of these plants should take advantage of conditions stimulating phloem activity and should avoid heavy applications of the more toxic materials which may destroy the phloem before translocation is completed.

Cereal, and probably other meristems, show stages of greatly increased susceptibility to 2,4-D. These appear to be periods of change from one type of development to another rather than periods of particularly rapid growth. Injury to crops can be reduced by avoiding 2,4-D sprays at periods when a large percentage of the plants are in susceptible stages.

Industry at Work in the Field of Herbicides

R. H. Beatty

It is certainly my pleasure to have this opportunity to speak to you regarding industry in the field of herbicides. We are enthused and encouraged with the progress made in this field the past few years through the cooperation of the college research and extension men, the county agents and weed supervisors, the U.S.D.A. coordinating research and regulatory agencies, and industry. It is through this cooperation and clear understanding of all the problems each group must face that we will continue to go forward.

Although I am very proud of the accomplishments of industry in this field and have some knowledge of the research work carried on by many of the leading companies, I am neither authorized nor qualified to speak as a representative of the industry. Rather, I would like to bring to you a discussion of how my associates and I view the obligation and responsibility placed on those in industry conducting research work on herbicides, particularly those concerned with 2,4-D and 2,4,5-T.

The word "industry" in the field of herbicides takes in a rather large and diversified group. We have in our manufacturing companies those few which are basic in the raw materials needed to produce 2,-4-D, 2,4,5-T, or both. We have other companies who are formulators, usually buying the acid and specializing in economical efficient formulation and distribution of the chemicals so they can be used by the consumer. Then, we have another group who buy esters or amines and formulate or simply repackage for consumer use. "Industry" also includes jobbers, dealers, custom sprayers and the manufacturers of spraying equipment, so you see we include quite a large group when we use the word.

This afternoon I would like to talk to you about research work as conducted by the herbicide manufacturer or formulator, because research work is done by both groups, naturally drawing my information from my experience with our own company and from associations with other companies in the work. I will try to acquaint you with some of the problems confronting the research men in industry, how they go about screening, formulating and developing new herbicides up to the time they are ready for the colleges' part in this cooperative program. Experiment station men tell me that it is this part of the program in which most of you are interested.

One primary requirement of a successful industrial research team is a thorough knowledge of the problems involved—I might say your problems or those of the farmer or ultimate consumer. To get the most out of our Research Department, all branches—the organic laboratory chemist, the agriculturist working on screening and field testing, the formulating chemist and the legal department—must be aware of the problem. For example, they must be informed of the latest research in the control of mesquite with 2,4,5-T or the most recent developments in the use of 2,4-D on potatoes. They must have a thorough and unbiased opinion of the success of 2,-4-D for the control of perennial weeds or its use in pre-emergence spraying. A successful research department must keep abreast of all research reported in the field so that time and money will not be wasted on experiments which have already been tried or for which there would be no commercial use. Such knowledge is gained from conferences such as this one we are attending and from reports of our technical

service, field research men and salesmen's contacts with jobbers, dealers and farmers.

Members of our Technical Service Department travel with the various salesmen, helping them educate jobbers and dealers on the many problems which arise. They also contact college research and extension men, offering them various formulations or new chemicals, whichever the case may be. In these contacts they learn your thinking on the many problems which arise, and they carry these suggestions back in the form of reports to our central research committee.

I don't believe any one man is ever responsible for the introduction and use of a new herbicide. It is true industry may screen a chemical for a particular purpose but through suggestions along the way from other research men or users, the chemical will often be diverted in another direction.

This was true of Ammate which was screened as a fire-proofing chemical but ended up in the field of brush control, and is true of 2,4-D which was originally synthesized by Dr. Pokorny in 1941 with the hope of obtaining a fungicide or bacteriacide. It did not fit into that field but later, through the work and suggestions of many men, found its place as a very effective herbicide. As I remember back to the early days of 2,4-D when it was a laboratory curiosity and still later when it proved effective on broad leaf weeds in grass, our expectations were strictly small package to home owners and possible golf courses or pasture work. We never dreamed that millions of pounds of 2,4-D would be manufactured for use on such agricultural crops as you are all aware of, and so no one man or group is responsible for the growth of chemicals in this field—it is the pooling of men's thinking and the cooperation of all agencies in the field.

In our company we have a Research Committee. This committee is composed of a chemist from our biological laboratory, a chemist from our formulation department, a horticulturist working on screening, an agronomist working on field testing, and members of our legal, library and technical service staffs. At the committee's meetings your problems are brought up and discussed by all the members. New chemicals are presented, new techniques are proposed and formulations to solve field problems are discussed. If this committee decides to attack the problem of brush control, for example, it is placed on the agenda and the necessary screening and field tests are laid out.

These screening tests are very important to industry and we are all looking for methods to improve our technique. All new chemicals synthesized in our laboratory are screened by the well known split pea test to evaluate their hormone properties against known checks such as indole acetic and naphthalene acetic acid. If a compound shows biological activity it is then reported to the research committee and further tests are planned. In the case of a potencial herbicide the cucumber test would be used for evaluation of root inhibition and the bean test for evaluation of shoot growth. 2,4-D would be used as the check in these tests. It would then be tested in our grass series, spraying and watering several species of grass including quackgrass with solutions of the chemical. If these tests indicated that it had possibilities, it might be screened further for pre-emergence work, soil sterility or brush control.

There is no doubt in our minds that we and others in this work have overlooked many active chemicals in our screening tests. Because of the countless important variations in concentration, formulation, method of application, and so on, no tests have yet been developed that can detect all types of useful activity. We must depend solely on the men carrying out this work, their thorough knowledge of the problems and alertness to small differences in compounds on points which may seem trivial at the time but which later prove of paramount importance.

The question is often asked, "Can a chemist deliberately synthesize a new chemical which will have a specified biological activity?" We don't believe we have reached that time yet but we are gradually building up experience by which the chemist is directed in his search for new compounds. An interesting conclusion has been reached by our chemists after working with a private research institute interested in basic work. Our laboratory made the whole series of chloro phenoxy acetic acids and sent them to the institute for a rating on biological activity. The rating report indicated to our chemists that in forecasting biological activity, the important point is not where the chlorine groups are placed on the ring, but where the unsubstituted positions on the ring are placed, the criterion for activity being that there should be two unsubstituted positions on the ring opposite one another. This, from the chemist's viewpoint, explains why 2,4,5-T is the only active position among the six trichlorphenoxy acetic acids known. Thus, you can see that as cooperation continues between industrial biological laboratories and those of government or private institutions interested in basic studies, we will continue to increase our knowledge of biological activity in relation to chemical structure.

Another important way of obtaining information to guide a research group is following closely the published literature. Since 1944 the published data in the field of herbicides and plant hormones has multiplied many times as you know well. We employ graduates in agriculture to screen carefully all the literature on the subject; pertinent information is brought to the attention of all research workers and many of these articles come before the research committee for discussion. Quite elaborate catalog files, cross-indexed by subject, author and source, are kept by a trained agriculturist. The literature is watched closely for mention of new chemicals or new developments pertaining to known compounds as they relate to plant physiology; for example, information on the movement of 2,4-D in the plant, the breakdown of 2,4-D in the soil or other basic problems.

We do not want anyone to get the impression that new formulations or new chemicals with biological activity are found easily or in great numbers. Industrial research laboratories produce an average of one compound worthy of field testing from every 3000 compounds screened. It is a very slow and expensive process with hard work for all.

Before leaving the subject of screening or synthe-

sizing new chemicals, I would like to say a word regarding the research conducted with so-called chemical by-products. It is obvious that in the complicated manufacture of agricultural chemical products, by-products also result. If a use for these by-products is not found, the laws of sound business procedure dictate that such compounds be charged against the product for which the process is being carried on. For example, if a manufacturer is to produce pure 2,4,5-T acid, he will probably start with 2,4,5 trichlorophenol. The manufacture of 2,4,5 trichlorophenol simultaneously produces 2,3,4 and 2,3,6 trichlorophenol for which no apparent market has yet been discovered even if they could be successfully separated from each other. Now, these two compounds may be called by-products in the manufacture of 2,4,5 trichlorophenol. However, until a use is discovered, the cost of their manufacture must be absorbed by the product which has a ready market—2,4,5-T. If industry finds a use for 2,3,6 or 2,3,4 trichlorophenol, then part of the cost of manufacturing 2,4,5-T can be allocated to the new compound, thus affording a lower possible price for 2,4,5-T acid.

The manufacture of agricultural chemicals is one of constantly keeping in balance all products made in the process so that the lowest price on any given product can be obtained, and it is one of the jobs of industrial research men to work toward this goal. It is natural that they, in a closely competitive business, should be interested in testing all by-products, but I can assure you that is a very small part of the screening work now being done.

After preliminary greenhouse studies show that a new chemical has promise, it is referred to our formulation chemist. Here, a different group of chemists determine the best commercial formulation for the chemical. Up until this time the chemical may have been in a very expensive solvent and possibly at very low concentrations, unsatisfactory for commercial merchandising methods. It is now the task of the formulator to use the proper combination of solubilizing agents, emulsifiers and wetting agents in order to make a balanced formula for the chemical that will be commercially acceptable as far as costs, effectiveness, storability and toxicity are concerned.

In this work the formulating chemist must be familiar with chemical markets as a whole, he must not only know the availability and costs of solvents, wetting agents, etc., but must make many experiments to find the proper combination of these chemicals and have a thorough knowledge of what the formula is expected to accomplish in the field. I don't know any better way to show you how difficult some of his problems are than to tell you that three years ago we found a form of 2,4-D which produced the finest results we had seen in pre-emergence work both in the greenhouse and in field trials. Yet this compound, as good as it is, has not been available even for extensive testing because of the difficulty of finding a practical solvent or commercial formula.

The chemical formulation of herbicides has moved through several stages of development. In the early days of 2,4-D we had salts, Carbowax emulsions and low concentration esters. The salts were improved and Carbowax products were discarded when low volume spraying made its appearance. The concentrated esters and amines were introduced because of their ease of application and because of the need for two distinct formulations for use under the great variety of crop and weed conditions.

At that time, differences were acknowledged in the selectivity and killing powers of salts, amines and esters. Now the recommendations of this conference clearly state that esters should be used at certain acid rates per acre, that amine dosages should be nearly doubled in comparison, and that the proportion of salt forms should be still further increased, recognizing the difference the formulation makes when comparable amounts of 2,4-D are used. Nevertheless we frequently hear people say there is no difference between 2,4-D formulations; that it is the amount of 2,4-D acid that counts, without further explaining the difference in performance of the salt, amine or ester forms.

I would like to carry this discussion one step further to the difference in effectiveness of formulation of 2,4-D acid in any one group. Amines can be formulated by placing the acid in the oil phase of an emulsion or in the water phase; although these are both amine formulations with equal amounts of acid, the reaction of treated plants would be different. This would also be true of water soluble esters and those which we are now using—the oil soluble esters. Hitchcock and Zimmerman (*Contrib. Boyce Thompson Inst.* 15:173-193. 1948) report that mixtures of 2,4-D and certain adjuvants were more effective herbicides than any of the individual components used at the same concentration as in the mixture, again emphasizing the variations that can be produced by the formulator.

We are now approaching a time when certain formulations within a group may help in treating the problem weeds which are not being satisfactorily controlled with today's amines and esters. Not only must our research men be conscious of the various formulations which can alter the effectiveness of their compounds, but they must also be aware of the differences in weed and crop reaction which appear when the substituted phenoxy ring is changed. 2,4,5-T and 2 methyl 4 chloro phenoxy acetic acid have shown definite evidence of selectivity and there are many more chemicals in this phenoxy group which show possibilities. Since we do not have full basic knowledge of chemical structure in its relation to plant physiology to guide us in selecting formulations, our only alternative is to test different formulations with regard to penetration and translocation, and different phenoxy compounds with regard to selectivity. It is in this capacity that the chemical formulator in industry can be particularly helpful in the research program.

While speaking of formulation I would be neglecting my task if I did not bring before you the rather new low volatility esters with which several chemical companies are working.

Our work has been carried on with the cooperation of Rutgers University (conducting the volatility study of various esters with regard to effects on tomato plants) and the Sowa Laboratory (conducting tests on the same esters to determine their chemical volatility). We have tested esters from methyl up

to those having 18 carbon atoms and although the work is not yet complete, it indicates that the laboratory test for chemical volatility and the plant tests on phytotoxic volatility roughly parallel each other on the straight chain carbon esters. That is, the longer the carbon chain the lower the physical volatility and the lower the phytotoxic volatility as tested on tomato plants. We also found that the same compound may show no phytotoxic volatility when tested on tomato plants, yet will produce leaf deformity on new growth of cotton plants.

This work will be continued and compounds will be released for extensive field testing this year with regard to their volatility and their effect on weeds and crops. Indications now point to a good and perhaps better weed killer in these new non-volatile esters.

Another problem which often comes before the formulator is the task of formulating to meet all types of water and variation of volume applied. In the area where we are now meeting there is a serious hard water problem, as industry's formulators well know. Testing hundreds of hard water samples and finding the most economical sequestering agents or non-ionic emulsifiers to use is all a part of good commercial formulations.

While screening and formulating are definitely a major part of industrial research, many companies carry the screening one step further to field testing. We heartily approve of this plan. We use a Field Test Plot in which we grow over 40 crops of interest such as corn, cotton, sugar beets, peanuts and flax. These crops are grown the length of the field and the chemicals applied both pre-emergence and post-emergence across all crops. Definite amounts of a variety of weed seeds are used in this test.

The second screening, or Field Test as it is called, is carried on in Saskatoon also, under quite different climatic conditions, soil structure and using different crops and weeds. We also have agents in many parts of the world who carry on Field Test work. It is quite helpful to have field tests going on in New Zealand during our winter months and to benefit from their results before our spring field tests start.

After these chemicals or formulations have gone through the tests outlined and have been discussed thoroughly by the Research Committee, they are turned over to the Development or Technical Service Department. Their policy has been to send the chemicals or new formulations to the various men in weed work at the colleges. This has been a harder job than it seems. We try to pick one or perhaps two men at a college to whom to send a new compound. This list is made up from past correspondence, from meeting various workers at conferences such as this one or by direct request from the research men or our Technical Department. We try to select men working on the problems in which these chemicals have a real place. Several colleges have developed Herbicide Committees made up of men from Agronomy, Horticulture, Forestry, and so on. Here, we simply notify the chairman of a new compound and it is then mentioned at a meeting; those interested in working with the chemical are later supplied through the chairman who makes known his wants for the college. I know we would all appreciate suggestions of better methods for distributing new chemicals which have been field tested.

Some of these compounds are sent to you under a laboratory number and a letter accompanies the material indicating what it should be used for and the tentative dosage as well as a note or warning on toxicity. Many times the actual chemicals or some of the components of the formula are not disclosed. This brings up the question of whether research men should work with compounds when the formula is not disclosed. I am in no position to answer that question except to say that in this extremely competitive field we must protect every formula or new chemical we have developed until proper sales rights have been obtained. That is the object of our industrial research and the only way it can continue is with revenue obtained from sales.

I believe I have covered the basic steps in developing compounds or new formulations up until the time they are offered to the U.S.D.A. or college research departments. We also use fellowships in several colleges to study problems which we are not equipped or staffed to cope with and we also use grants in aid to help with a particular problem which will be beneficial to the herbicide problems in general. Obviously, this is not the way all companies conducting research in this field develop a product; I have tried to present a point of view based on our own work.

In summary, we would like to emphasize still greater cooperation between Federal and state supported institutions on one hand and the laboratories and research organizations of private corporations on the other hand. A step forward would be for Federal research to carry out more fundamental studies on the basic biological problems related to the field of herbicides. Examples of such work would be studies on the translocation of these chemicals, their ultimate breakdown in the plant or the chemical changes which dissipate its effectiveness, or further study on the type of fungus or organism responsible for the breakdown of systemic herbicides in the soil, all these studies uncovering reasons why certain chemical structures are best suited to perform specific functions. If such information was available to industry it would definitely result in better herbicides. This type of fundamental research belongs to the United States Department of Agriculture rather than to industry because of the competitive nature of the agricultural chemical field. Private research must be carried on with the profits derived from the sale of herbicides and a study of this part of our business would not leave much doubt in anyone's mind how far industry can go in the field of fundamental research.

In closing, we in industry would like to pay our respects to the men responsible for organizing and carrying out the various duties in the weed control conferences throughout the United States and Canada.

Spearheading activity and concentrated research in controlling weeds, the North Central Weed Control Conference has contributed immeasurably to the successful use of herbicides, especially 2,4-D and 2,4,5-T, in this country. You have, through your clear-cut policy reports and research reports, helped tre-

mendously in producing the uniform directions being used for commercial products. Through the research reports you have encouraged and directed the vast amount of industrial, government and private research now in progress. I know you have the wholehearted support of industry and through this continued cooperation of all the branches in our field we will continue to progress.

Recommendations of the Research Committee of NCWCC for 1950

B. H. Grigsby, Chm.

The following discussions, opinions, suggestions and recommendations are made in the light of the best information accumulated in 1949 by the Research Committee of the NCWCC. The Conference recognizes that the effectivenes of herbicidess depends on so many factors which vary from region to region and that this report can in no way replace state and local recommendations. It is suggested, therefore, that specific recommendations on the use of herbicides locally be obtained from your state agricultural experiment station and, or state regulatory officials.

A. Control of Perennial Weeds

Many perennial weeds are difficult to control with 2,4-D. Best results have been obtained by treating during the active growing stage—generally near the bud stage. One application of 2,4-D seldom gives eradication. Repeat treatments are necessary. Where long time control, under cropping conditions, is the objective, the rate of application should be governed by the maximum amount that the crop will tolerate.

The Research Committee recognizes the value of chlorates, borates, and similar chemicals for the control of perennial weeds. These chemicals are especially valuable for obtaining quick eradication of small patches of such weeds. Rates of application in the range of 3 to 6 pounds per square rod for chlorates and 15 to 30 pounds per square rod for borates probably will be required. The recommended rate for the various species of weeds should be obtained from local experiment stations. These chemicals will sterilize the soil for a period of one or more years.

1. *Canada Thistle*

To eradicate Canada thistle, repeated applications of 2,4-D over a period of several years are generally necessary. The first application should be made at the bud stage and retreatments made when the resprouting thistle plants are in the rosette stage. From 1/2 to 2 pounds of 2,4-D per acre is suggested as a range of application.

2. *Perennial Sowthistle*

2,4-D has given effective control of perennial sowthistle in cereal crops when applied at approximately 1/2 pound per acre. Three-quarters to 1 1/2 pounds applied at the bud-flower stage has resulted in nearly complete eradication, especially when the weed is in competition with aggressive grasses. Repeated treatments are generally necessary to eliminate surviving plants.

3. *White Top or Hoary Cress*

Hoary cress may be effectively controlled by 2,4-D. Seed production is prevented, top growth stopped, and the stand reduced by one application at the bud to early bloom stage. Repeated treatments over a period of three or four years, have resulted in elimination of the weed in grass sod and on cultivated land in connection with cultivation and the growth of crops. Since hoary cress is moderately tolerant to 2,-4-D the esters should generally be used. Treatments at rates of one and one-half to two and one-half pounds per acre in early bloom and/or fall rosette stages are recommended. These rates will injure most crops. Plants that emerge within 3 or 4 weeks after treatment should be spot treated.

4. *Field Bindweed*

Field bindweed is most susceptible to 2,4-D when just starting to bloom but may be controlled at other stages if growing vigorously. One-half to one pound of 2,4-D per acre is required to give practical control of this weed.

5. *Leafy Spurge and Russian Knapweed*

2,4-D is useful in controlling leafy spurge and Russian knapweed in growing crops when applied at approximately one-half pound per acre.

On non-cropped land, especially where spurge is in competition with an aggressive grass, a measure of control may be obtained through an application of one pound 2,4-D per acre. Treatments are more effective when made at the bud and bloom stages. Repeated applications are necessary.

Chlorate and borax compounds may be used for the eradication of small patches of these weeds.

6. *Horse Nettle*

From one and one-half to two pounds 2,4,5-T per acre, or 2000 ppm., applied as a wetting spray, has given substantial reduction in stands of horse nettle. Time of application is important and the best results have been obtained at the full bloom stage.

7. *Perennial Weedy Grasses*

TCA is effective for the control of established stands of quack, Bermuda, Kentucky blue, *Muhlenbergia spp.*, and brome grasses when applied at the rate of 80 to 100 pounds per acre. Johnson grass is more difficult to control but promising results have been obtained with 100 pounds per acre. Best results are obtained with Johnson grass when the spray is applied to the tops of growing plants. Best results are obtained when optimum moisture conditions for plant growth prevail. Excessive rainfall soon after treatment may reduce the effectiveness of TCA.

Smaller amounts of TCA have given excellent results on quack grass when used in conjunction with plowing or disking of the soil. One procedure is to plow the land 2 to 4 weeks after the chemical is applied. Another is shallow plowing followed immediately by spraying. For such use, 40 to 50 pounds TCA per acre are suggested.

Residual toxicity from TCA sometimes disappears in a few weeks but may persist for one year or long-

er. Crop susceptibility varies and extensive studies are needed.

B. Control of Annual Weeds

2,4-D can be used to control many annual weeds. However, some species are resistant. Annual weeds are more susceptible in the seedling and early stages of development, and when conditions are such as to promote vigorous growth. Some weeds which are resistant at later stages of growth are readily killed when young and actively growing. A dosage as low as 1/8 pound will control some annual weeds but the local state experiment station should be consulted for information concerning the dosage necessary for the control of specific weeds.

Practically all of the annual broad leaved and grass weeds can be controlled in the seedling stage by means of cultivation, flame burners, and, or contact or residual herbicides. Dinitrophenols, pentachlorophenols, pentachlorophenates, aromatic oils salt, chlorates and borates can be used to control annual weeds. Varying periods of soil sterilization may follow the application of most of these chemicals. State recommendations for the use of the above chemicals should be followed.

C. Use Of Herbicides In Growing Crops

1. *Legume Seedings in Grain*

The use of dinitro sprays is recommended for control of broad leaved weeds in grain when legume seedings must be maintained. Use of from 6 to 8 pints of products with a 13 percent active ingredient content, in 60 to 80 gallons of water is suggested.

Maintenance of legume seedings in grain following treatment with 2,4-D is markedly influenced by local conditions. Such treatment is hazardous and usually will result in some reduction in legume stand. The following factors are known to favor maintenance of legume stand:

1. Application of not more than ¼pound 2,4-D per acre.
2. Use of sodium and amine salts of 2,4-D.
3. Application of sprays when wheat is 8 to 10 inches high, measured to tip of extended leaves.
4. Use of ladino, alsike, medium red and mammoth clovers. Alfalfa and sweet clover are less tolerant to 2,4-D than the other legumes listed.

2. *Flax*

Flax should be sprayed with 2,4-D as soon as there is enough emergence of susceptible species of weeds to make spraying practical. Flax may be badly injured if sprayed in bud or bloom stages.

Amine salts, sodium salts, and esters of 2,4-D may be used; however, smaller dosages of ester than of the salts are recommended.

The dinitros may be used for the control of wild mustard, stinkweed and certain other broad leaved annual weeds. Local recommendations as to herbicides, dosage and susceptible varieties of flax should be followed.

3. *Spring Planted Wheat, Oats and Barley*

2,4-D should not be applied to these grain crops before they have reached a height of 4 to 6 inches. A maximum of ¼ to ½ pound 2,4-D per acre may be applied before the fully tillered stage and a maximum of ½ to ¾ pound per acre after the fully tillered stage—except from the boot to dough stage—without appreciable reduction of yields or viability of the grain. Abnormal heads may be produced when treatments are applied at the earlier stages. The lower suggested rates should be considered as the maximum amount when esters are used.

4. *Fall Planted Wheat, Oats and Barley*

Wheat.—At its most resistant stages winter wheat ordinarily will tolerate dosages large enough to control most annual weeds without serious injury to the crop. Damage from 2,4-D treatment seems most likely to occur during the boot and heading stages; therefore, spring applications should be made after the crop is fully tillered and before it reaches the boot stage, or be delayed until after the kernels are in the dough. Fall applications are not recommended. Rates of ¼ to 1/3 pound 2,4-D as an ester or ½ to 2/3 pound 2,4-D as an amine or sodium salt will usually be sufficient for annual weed control if applied before the boot stage. Large weeds sprayed later in the season require more 2,4-D and weed control often is not satisfactory. Where heavy rates are necessary to control perenniel weeds some damage to the crop may occur.

Barley and Oats.—Only limited information is available, but these crops seem to be similar to wheat in their reactions.

5. *Corn*

Post-emergence—The practice of spraying with 2,4-D for the control of weeds in corn is recommended in fields where weeds cannot be controlled by ordinary cultivation. Under most conditions it should not be relied upon to replace cultivation but may be used in conjunction therewith.

Some injury to corn, regardless of dosage, should be expected. Lodging, brittleness, curvature of stalks and malformation of brace roots are the symptoms. Such symptoms of injury may or may not affect yields. Reductions in yield are often caused by reduced stands due to breakage of stalks during the period of brittleness following spraying. The degree of injury is increased as dosage of 2,4-D is increased. One-half pound of 2,4-D acid per acre should be considered the maximum dosage. Sodium and amine salts usually cause less injury to corn than esters when applied at equal rates.

Differences in tolerance of strains and varieties of corn to 2,4-D should be recognized. When spraying corn, especially inbred or seed fields, of unknown or low tolerance, dosages of 2,4-D should be reduced to the minimum required to control weeds.

Time of applications should be timed to most effectively control weeds. When large corn is sprayed the use of "drops" or nozzle extensions will reduce danger of injury. Small corn appears to be more tolerant to 2,4-D than corn 10-36 inches in height, at least less subject to breakage of stalks following spraying. Moisture condition and temperature favorable for corn growth are conducive to injury.

Pre-emergence—Effective, pre-emergence treatment of corn with herbicides is dependent upon a number of factors, particularly moisture and the time

of germination of weed seeds. Pre-emergence treatments of corn with 2,4-D, are not recommended on sandy soils, acid soils or soils of low fertility.

Pre-emergence treatments are recommended where weed control problems cannot be solved by other means. Pre-emergence treatments should usually be applied 5 to 7 days after planting. One and one-half to two pounds of 2,4-D per acre will give good weed control with a minimum reduction of corn yields.

Pre-emergence treatment is not a substitute for cultivation.

6. *Sorghums*

Sorghums may be seriously injured by 2,4-D application. Sorghums should be sprayed only when the weeds present cannot be controlled by other methods. When 2,4-D is used, only the minimum dosage necessary for weed control should be applied, usually ¼ to ½ pound 2,4-D per acre. Some varieties may tolerate a heavier dosage while a few varieties may be injured by very light applications. Considerable brace root abnormality, which may or may not be accompanied by lower yields, can be expected.

7. *Sugar Beets and Soybeans*

No chemical treatment for weeds in sugar beets or soybeans has given sufficiently consistent results to be recommended for farm use in 1950. Several chemicals appear promising for future study to determine their limitations and possibilities.

D. Horticultural Crops

Chemical weed control measures with horticultural crops should be thought of as only an aid to cultivation and not as a substitute for cultivation. With the exception of carrots and corn, a great deal more research is required before general suggestions for the use of herbicides in truck crops can be made. In carrots light oils with an aromatic content or approximately 10-16% are suitable for the control of annual weeds and grasses. 2,4-D can be used in sweet corn but definite varietal differences in the tolerance to 2,4-D exist. State recommendations in regard to variety response should be followed. For post-emergence use the maximum safe dosage is ¼ pound ester and ½ pound of salts. The results now available do not warrant general recommendations for the use of pre-emergence treatments with 2,4-D in sweet corn.

Pre-emergence treatments in asparagus, beans, beets, onions, spinach and melon crops have shown promise but no specific recommendations can be made. Pentachlorophenols, dinitrophenols, 2,4-D and aromatic oils offer considerable promise, but suitable rates and time of applications have not been fully determined.

Post-emergence usage of herbicides can be made in asparagus, onions, potatoes, beets but the results that can be expected are dependent on a number of factors and state recommendations should be followed. In asparagus, cyanamid is safe for the control of young annual weeds. The use of 2,4-D in asparagus is a questionable procedure. Asparagus plants are not usually killed by ¼ to 1 pound per acre, but productivity of the beds may be reduced by repeated treatments.

Onions may be sprayed with sulfuric acid, potassium cyanate or sodium PCP but climatic factors affect the results to such an extent that regional suggestions are not warranted.

2,4-D and dinitrophenols are not safe for use in beets.

TCA should not be used in horticultural crops, in small fruits nor under fruit trees.

The use of 2,4-D is suggested for the control of weeds in first-year strawberry beds and in non-fruiting older plantings, but 2,4-D should not be used on flowering or fruiting strawberries. Newly set strawberry plants should not be sprayed until such plants are well established in the soil.

Weeds in raspberries can be controlled with 2,4-D provided that direct application of the spray to growing tips is avoided.

The use of 2,4-D for weed control in or near vineyards at any season of the year is hazardous and is not recommended. Annual weeds in grapes can be controlled by contact herbicides provided that the spray does not come into contact with the vines.

The use of 2,4-D and 2,4,5-T, for weed control in orchards has shown promising results. However, the long-time effects of these chemicals on fruit trees have not been determined and they are not recommended for use in orchards.

Ammonium sulfamate at a concentration of 3/4 pound per gallon of water is suggested for the control of poison ivy in orchards. Annual weeds may be controlled by the use of various contact herbicides. In using herbicides in orchards direct contact of the spray with the trees should be avoided.

F. Woody Plants

It now appears that 2,4,5-T has a definite place in the woody plant program, because it will kill some woody plants that are not killed by 2,4-D.

For killing woody plants sensitive to foliage sprays of 2,4-D or 2,4,5-T, concentrations of at least 2000 ppm (.2 percent) of the esters where drift and volatility are not problems, are recommended.

Only during the month of May can 2,4-D be applied to give a satisfactory kill of sand sage. The esters of 2,4-D should be applied at the rate of 3/4 pound per acre. The amine and sodium salts should be used at 1 pound. Both of these rates should be increased by ¼ pound during dry seasons. The esters of 2,4-D should be applied in 3 gallons of oil or 1 gallon of oil plus 4 gallons of water per acre. The latter mixture is suggested for use in applying amine or sodium salts.

High concentrations of 2,4-D or 2,4,5-T in oil applied to surfaces of stumps and canes cut as closely as possible to ground level will kill some shrubs and trees that are tolerant to foliage sprays of 2,4-D.

No minimum concentration has been determined, but not less than 2 percent, should be used. This treatment may be used at any season of the year.

Mixtures of 2,4-D and 2,4,5-T applied to cut surfaces should give a wider range of kill.

For general foliage spraying of mixed brush populations, mixtures of 2,4-D and 2,4,5-T appear to be satisfactory. 2,4,5-T has given best results on brambles and several hardwood species.

Applications of dry ammonium sulfamate to the

cut surfaces of stumps is recommended to prevent sprouting of most species of woody plants.

Ammonium sulfamate and sodium chlorate are recommended for control of woody plants in situations where 2,4-D and 2,4,5-T cannot be used.

Dormant applications of at least 1 percent 2,4-D or 2,4,5-T in oil, have given promising results and should be given more extensive field trials.

G. New Herbicides

A number of new herbicides, reported on by abstracts in the 1949 Research Report, have been more or less extensively tested. None of these are to the point where the Research Committee can recommend them for general use.

Report Of Committee On Terminology

Chemical Names and Designations.—The name of the chemical is given in (a) followed in (b) by the forms adopted for common usage. In some instances materials are well known by trade names, but all such designations have been omitted.

1. (a) 2,4-dichlorophenoxyacetic acid
   (b) 2,4-D, acid (indicate carrier or solvent)
   2,4-D, sodium salt
   2,4-D, amine salt (indicate which)
   2,4-D ester (indicate which)

2. (a) 2,4,5-trichlorophenoxyacetic acid
   (b) 2,4,5-T, acid
   2,4,5-T, salt (indicate which)
   2,4,5-T, ester (indicate which)

3. (a) 2-methyl-4-chlorophenoxyacetic acid
   (b) MCP, acid
   MCP, salt (state which)
   MCP, ester (state which)

4. (a) trichloroacetic acid
   (b) TCA, acid
   TCA, ammonium salt
   TCA, sodium salt

Rates and concentrations of the above listed materials shall be stated as the acid equivalent.

5. (a) pentachlorophenol
   (b) PCP, phenol (state "in oil" or other carrier
   PCP, sodium salt

6. (a) 4,6-dinitro-o-cresol
   (b) DNOC, ammonium salt
   DNOC, sodium salt

7. (a) 4,6-dinitro-o-hexylphenol
   (b) DNOCHP, phenol (state form or carrier)
   DNOCHP, salt (state which)

8. (a) 4,6-dinitro-o-sec-butylphenol
   (b) DNOSBP-phenol (state carrier)
   DNOSBP-amine salt
   DNOSBP-ammonium salt

9. (a) 4-6-dinitro-o-sec-amylphenol
   (b) DNOSAP, phenol (state carrier)
   DNOSAP, salt (state which)

10. (a) phenyl mercury acetate
    (b) PMA

11. (a) isopropyl-n-phenylcarbamate
    (b) IPC

12. (a) sodium tetraborate
    (b) borax

13. (a) sodium chloride
    (b) salt

For the chemicals listed below and any others not listed, use the complete chemical name. Do not report results under trade names.

14. ammonium sulfamate
15. sodium chlorate
16. sodium arsenite
17. methyl bromide
18. carbon disulphide
19. sodium thiocyanate
20. calcium cyanamide
21. sodium cyanamide
22. potassium cyanate
23. sodium isopropyl xanthate
24. allyl alcohol

Definition Of Terms

1. *Preplanting treatments*: An application made to the soil before the crop seeds or plants are placed in the soil.

2. *Pre-emergence applications* are of two kinds: (1) *Contact pre-emergence* - an application made after weed emergence but before the crop has emerged; (2) *Residual pre-emergence* - which kills weeds as they emerge or as the seed germinates, either before or after the crop has emerged.

3. *Soil sterilant*: A material which renders the soil incapable of supporting plant growth. Sterilization may be temporary or relatively permanent.

4. *Contact herbicide*: A chemical or combination of chemicals that kills by contact with plant tissue but is not appreciably translocated.

5. *Low volatile esters*: The esters of 2,4-D, 2,4,5-T and other similar herbicidal compounds that have low volatility should be designated as low volatile esters and not as non volatile esters.

6. *Rate and dosage*: These terms are synonomous, with "rate" the preferred term. Rate refers to the amount of active material (such as 2,4-D acid equivalent) applied to a unit area (such as one acre) regardless of percentage of chemical in the carrier.

7. *Concentration*: The proportion of active ingredient in the carrying medium and is to be designated as a percentage or ppm of this medium.

8. *Herbicide*: A chemical known to be toxic to some chlorophyll bearing plants.

Resolutions

1. Realizing the confusion of the ultimate users of present commercial formulations of 2,4-D and 2,4,5-T resulting from the wide variation in percentage of acid content in these formulations, the North Central Weed Control Conference begs the consideration of all commercial formulators in standardizing these products in both the U. S. and Canada. It is suggested that these standards of 2,4-D acid content of the amine and ester formulations be established on the basis of facilitating the accurate recommendations and field use of these materials in simple pint or quart units of measurements. The conference further recommends that labels of containers of 2,4-D and 2,4,5-T indicate the parent acid content in reference to the simple units of liquid measure in the container.

2. Realizing the tremendous annual loss caused by weeds, and further realizing the wide-spread weed seed dissemination by combines and threshers and that present designs of this type equipment contribute greatly to this condition;

be it resolved, that the North Central Weed Control Conference respectfully request the consideration of this problem by the machinery manufacturing industry, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Engineering departments of the Land Grant Colleges for the purpose of designing equipment for easy cleaning.

3. The committee on publications has investigated the possibilities and feasibility of the North Central Weed Control Conference undertaking the responsibility of publishing a journal devoted to articles concerned with weed control research and related topics. On the basis of their investigations, the following resolution is offered:

Insofar as the North Central Weed Control Conference is not now in an adequate position financially or physically to undertake the responsibility of editing, publishing and circulating a journal devoted to weed control topics,

be it resolved, that this currently needed publication be proposed and recommended as a prime objective of the newly formed National Association of Regional Weed Control Conferences.

4. This conference and all agriculture of the country and more especially those engaged in weed work, including regulatory officials, research and extension workers, have lost a good friend in the withdrawal of Mr. L. W. Kephart from the service of the U. S. Dept. of Agriculture. It is regretted that his withdrawal was found necessary after so long a valuable service to his government and his countrymen.

Mr. Kephart labored, long and hard, faithfully and diligently, for the welfare of agriculture. For years he continued alomst single-handed to work for more research, education, laws and programs to aid in the fight against the nations weed menace.

Therefore, be it resolved by this conference that we express heartfelt appreciation to Mr. Kephart for his many long yars of continuous service as a government worker helping to aid the people of our land toward a solution of their age-old weed problem.

Be it further resolved that this resolution be printed in our conference proceedings and that copies be sent to Mr. Kephart and to the Chief of the Bureau of Plant Industry, Soils and Agricultural Engineering.

5. Whereas, the North Central Weed Control conference in its sixth annual meeting has enjoyed the wonderful hospitality of the great state of South Dakota, and its various institutions and agencies, the excellent facilities of the city of Sioux Falls, including its hotels, newspapers, radio stations, Chamber of Commerce, American Legion and Churches, and the farm journals and magazines, and

furthermore, after enjoying a conference due to the untiring efforts of the officials of the conference, the various committees, and especially the chairman of general arrangements, Mr. Chas. Gilbert and his efficient staff of co-workers,

be it resolved that this conference express to them our deepest appreciation and heart-felt thanks for a highly successful and profitable conference which we know will result in great good to the people of our land.

Signed ——
Resolutions Committee
Clyde A. Bower, Chairman
George Briggs and
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